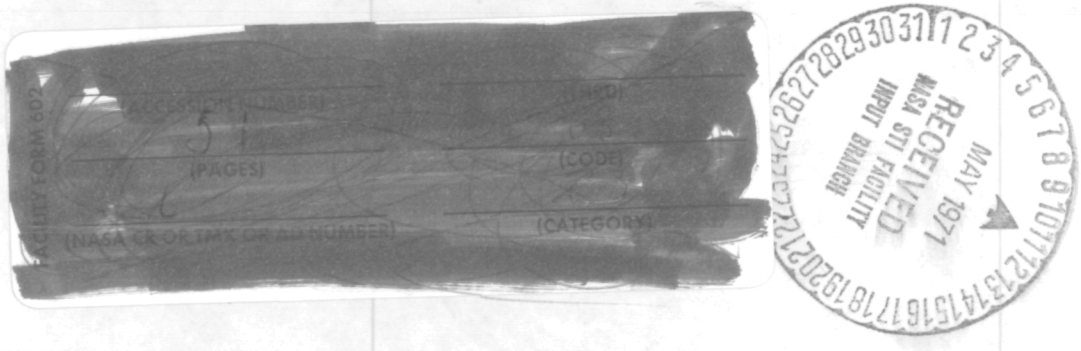
N71-23829

Page One Title

SOUND LEVEL MEASUREMENTS PERCENT BAND AND OCTAVE BAND ANALYSIS OF THE NOISE AND VIBRATION IN INDUSTRIAL INSTALLATIONS

L. F. Delbonne, J. R. da Costa and E. J. Cury

Translation of "Medicoes em Niveis Globais, Analise em Faixas de Oitavas e en Faixa Percentual do Baruliko e das Vibracoes em Instalacao Industrial," Laboratorio de Acustica e Sonica, Sao Paulo, Brazil, Tech. Report 6910.386, October 1969, pp. 1-48.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C., 20546 APRIL 1971

Even Roman Odd

Report 6910.386 Copy No. 016

Measurements of overall levels, octave and percentage bandwidth analysis of noise and vibrations at the industrial plant of Conexoes do Ferro Foz S/A, Rua Antonio Lobo, 82, Penha, Sao Paulo.

TABLE OF CONTENTS

0.00	Summary	1
1.00	Purpose	1
2.00	References as to Locations of Measurements	2
3.00	Instruments and Accessories, Procedures	2
4.00	Measurement Results	3
5.00	Considerations on the Noise Levels	18
6.00	Observations Concerning the Motors and Compressors	19
7.00	Floor Plans, Figures. Spectrographs	22

SOUND LEVEL MEASUREMENTS PERCENT BAND AND OCTAVE BAND ANALYSIS OF THE NOISE AND VIBRATION IN INDUSTRIAL INSTALLATIONS

L. F. Delbonne, J. R. da Costa and E. J. Cury

ABSTRACT: The report presents the results of sound level measurements and analysis at a typical foundry. Nineteen locations were selected throughout the plant to be subjected to the sound analysis. In addition, certain motors and compressors were analyzed for noise vibrations. Conclusions and recommendations based on the study are presented in Section 5.00.

Summary No. 236/386 /2*

[1]7.2/12.11 Overall Sound Level Measurements, percentage octave band analysis of noise and vibration at an industrial plant--L. F. B. Delbonne and J. R. da Costa--Laboratorio de Acustica e Sonica S/C/L, P. O. Box 12,946, Sao Paulo---Report 6910.386--48 pages, 31 Figures (October 10, 1969).

The report describes the equipment and accessories used, the results of measurements, and the operating conditions at an industrial environment, in view of current legislation, concerning annoyance and auditory protection. The problem was studied as well as its practical solutions. Several measurements were taken of acceleration, velocity and displacement and the results were studied. These results are presented in the form of octave and percentage band spectrum tables and graphs.

1.00 - Purpose /3

The purpose of this report is to present the results of and observations on measurements and analysis of the noise and vibrations produced in the plants of Conexoes de Foz S/A on 82 Antonio Lobo Street. The primary purpose of the project was to determine the industrial environmental conditions relative to noise and its consequences; to ascertain the legal implications of annoyance

---

*Numbers in the margin indicate pagination in the foreign text.
[1]Subject Classification according to the Acoustical Society of America.

with respect to the workers and to examine the economic feasibility of providing industrial buildings with acoustical and anti-vibration protection.

2.00 References as to Locations of Measurements

The industrial plant is located at 82 Antonio Lobo Street, Penha de Franca, where the study was conducted. Figure 386-1/31 shows the plant floor plan with a description of the points where the measurements were taken. The facility is primarily a foundry. Naturally there are production and storage areas. The noise studied is characteristic of foundries, thus offering a full concentrated band in the lower audio frequency spectrum. A significant variation in the sound levels was noted from beginning to end of operations typical of the kind of work performed, but in any case the noise can be considered as continuous and not intermittent.

3.00 Instruments and Accessories. Procedure

Bruel and Kjaer equipment was used as the basic measuring method along with the necessary accessories.

The basic device was a Bruel & Kjaer model 2203 Precision Sound-Level Meter, equipped with a odel 4131 condenser microphone. The octave band analysis was performed with a set of Bruel & Kjaer Model 1613 octave filters. The noise was recorded on full track magnetic tape using an Ampex Model 2160 recorder. The acoustical instruments were all previously calibrated using a Model 4220 piston phone (calibration certificate 80,301 of September 1967) and further adjusted to the reference furnished by the manufacturer. The magnetic tape was fed to a Model 2107 Percent Band Analyzer and then recorded on a Bruel & Kjaer Model 2305 Grafic Level Recorder. The accelerometer was a Bruel & Kjaer Model 4330 (separate calibration certificate No. 59,801). Determination of displacement was accomplished with a Model ZR-0020 pickup. /4

There are several publications and recommendations which deal with the measurement and analysis of industrial noise. However, in this case, what was being attempted was the examination of noise in the environment, and not a detailed study of each machine for the purpose of modifying its design. Therefore, the suggestions and recommended procedures found in the specialized

literature that bears on the present case were followed. The details of the procedure and its full justification can be found in the following publications: [1-10].

4.00 Measurement Results

/5

Nineteen locations were chosen for taking measurements. The selection was based on the presence of a large number of workers as well as locations where above-normal levels occurred. Of these nineteen locations, overall level measurements were made at all the compensation scales approved by the ISO UNO and at eight of them recordings were made for percentage band observation of studied noise. In addition to this, the excessive vibration of one of the motors in the compressor room was noted. The accelerometer was used on two motors and the proportional band measurement of the acceleration of both motors and of the acceleration, velocity and displacement of compressor No. 3 and motor No. 3 for purposes of study. The conclusions of these observations will be described later.

4.10 Location 1 in Figure 386-1/31 Tool Room

Compensation scale	A	B	C	D
Maximum levels, db	88	91	89	91
Minimum levels, db	87	90	88	90

Octave Band Analysis

/6

Center frequency, Hz	Band level	
	Maxima	Minima
31.5	81	80
63	85	84
125	77	76
250	83	82
500	83	82
1,000	81	80
2,000	80	79
4,000	78	77
8,000	75	74
16,000	75	74
31,500	51	50

Figure 386-2/31 shows the octave spectrum, along with the ISO/UNO 85 db curve. It is noted that the sound level is exceeded not only at the overall level, whose limit would be 85 db, but in view of the high intensity on the narrowband of the spectrum, such noise is unpleasant. The ISO/UNO 85 db curve is not reached, although it exceeds the overall level. Figure 386-21/31 shows the percentage band spectrum confirming a wideband spectrum.

4.20 Location indicated by 2 in Figure 386-1/31 Production Threading

Compensation scale	A	B	C	D
Maximum levels, db	98	98	99	99
Minimum levels, db	97	97	98	98

Octave Band Analysis

Center frequency, Hz	Band Level Maxima	Minima
31.5	85	84
63	84	83
125	84	83
250	86	85
500	89	88
1,000	100	88
2,000	88	87
4,000	86	85
8,000	88	87
16,000	76	75
31,500	63	62

/7

Figure 386-3/31 shows the octave-band spectrum. Note that the overall level considerably exceeds the established 85 db limit just as the curve is exceeded making the environment totally annoying with respect to the noise levels. The percentage band spectrum, shown in Figure 386-22/31, indicates further that the noise possesses a full band with a high concentration of intense components at the high frequencies.

4.30 Location 3 in Figure 386-1/31 Cleaner

Compensation scale	A	B	C	L
Maximum levels, db	96	97	98	99
Minimum levels, db	95	96	97	98

Octave Band Analysis

Center frequency, Hz	Band Level Maxima	Minima
31.5	83	82
63	81	80
125	86	85
250	84	83
500	89	88
1,000	93	92
2,000	86	85
4,000	85	84
8,000	81	80
16,000	72	71
31,500	55	54

/8

Figure 386-4/31 shows the octave-band spectrum. Note that the overall level is exceeded as well as the 85 db curve which makes the environment annoying from the viewpoint of sound. The curve has the same form as that shown in the previous figure for location No. 2 in the same environment. Figure 386-3/31 and 386-4/41 display a similar form and both point up the need to take steps to protect the auditory system of the workers.

4.40 Location No. 4 of Figure 386-1/31 Threading Machines

Compensation scale	A	B	C	L
Maximum levels, db	92	94	96	97
Minimum levels, db	91	93	95	96

	Octave Band Analysis Band level	
Center frequency, Hz	Maxima	Minima
31.5	83	82
63	81	80
125	83	82
250	87	86
500	89	88
1,000	88	87
2,000	87	86
4,000	84	83
8,000	75	74
16,000	63	62
31,500	41	40

Figure 386-5/31 shows the octave-band spectrum. Note that the curve differs from the last two in harmonic content since there is no high intensity of high frequency components [word blurred] flattened. The level is excessive and the 85 db curve is exceeded.

4.50 Location No. 5 in Figure 386-1/31 Production/Maintenance /9

Compensation scale	A	B	C	L
Maximum levels, db	89	90	92	94
Minimum levels, db	88	89	91	92

	Octave Band Analysis Band level	
Center frequency, Hz	Maxima	Minima
31.5	88	87
63	82	81
125	82	81
250	85	84
500	86	85
1,000	85	84

Octave Band Analysis		
Center frequency, Hz	Maxima	Minima
2,000	83	82
4,000	79	78
8,000	75	74
16,000	66	65
31,500	45	44

Figure 386-6/31 shows the octave-tand spectrum. Note that, despite the fact that the overall 85 db level is exceeded, the 85 db curve is not exceeded but just on a tangent with the maxima. The annoyance, although legal, is not excessive.

4.60 Location No. 6 on Figure 386-1/31 Cleaner/Emery-Wheels

Compensation scale	A	B	C	L
Maximum levels, db	91	93	94	95
Minimum levels, db	90	92	93	94

Octave Band Analysis Band level		
Center frequency, Hz	Maxima	Minima
31.5	85	84
63	87	86
125	85	84
250	86	85
500	85	84
1,000	84	83
2,000	83	82
4,000	82	81
8,000	79	78
16,000	71	70
31,500	52	51

/10

Figure 386-7/31 shows the octave-band spectrum. Note, in this case, that the overall level is above that recorded for location No. 5 when the spectrum

and 85 db curves were tangent to one another, and that the 85 db curve is not quite reached. This is because, despite the fact that the level is raised, the intermediate frequency components are not so intense. The result is a flat spectrum so as not to reach the legally established curve.

4.70 Location No. 8 in Figure 386-1/31 Drum/Cleaner

Compensation scale	A	B	C	L
Maximum levels, db	95	95	95.5	96
Minimum levels, db	94	94	94.5	95

Octave Band Analysis

Center frequency, Hz	Band level Maxima	Minima
31.5	74	73
63	76	75
125	78	77
250	79	78
500	86	85
1,000	89	88
2,000	87	86
4,000	88	87
8,000	84	83
16,000	79	78
31,500	53	52

/11

Figure 386-8/31 shows the octave-band spectrum. The 85 db curve is exceeded because the noise at the location contains intense components, in the center band of the audio frequency, which exceed the curve. In this case, because of the intensity of components in the intelligibility band, something must be done to reduce the intensity of the components in such a band. In the present situation, comprehension is very difficult. This prevents any worker from understanding clearly what a fellow worker is saying, and this can result in not being able to heed warnings. The results can be serious should someone try to warn another worker of a danger. Figure 386-23/31 shows the percentage band spectrum. The major amplitudes for the intermediate frequencies are noted.

4.90 Location No. 9 in Figure 386-1/31 Furnaces

Compensation scale	A	B	C	L
Maximum levels, db	88	91	92	94
Minimum levels, db	87	90	91	93

Octave Band Analysis

Center frequency, Hz	Band level Maxima	Minima
31.5	83	82
63	79	78
125	86	85
250	83	82
500	81	80
1,000	78	77
2,000	75	74
4,000	72	71
8,000	65	64
16,000	52	51
31,500	34	33

/12

Figure 386-9/31 shows the octave-band spectrum. Note that, despite the overall level being higher than admissible, the 85 db curve is not even reached, and is separated by 4 db in the 250 Hz region. In any case, annoyance is problematic.

4.100 Location No. 10 in Figure 386-1/31 Emery Wheels

Compensation scale	A	B	C	L
Maximum levels, db	91	93	95	97
Minimum levels, db	90	92	94	96

Octave Band Analysis

Center frequency, Hz	Band level Maxima	Minima
31.5	87	86
63	93	92

Center frequency, Hz	Maxima	Minima
125	91	90
250	89	88
500	87	86
1,000	85	84
2,000	82	81
4,000	77	76
8,000	77	76
16,000	70	69
31,500	50	49

Figure 386-10/31 shows the octave-band spectrum. Note that the 85 db curve is exceeded by the maxima and is tangential with the minima. For overall level is above the admissible level which results in an annoying environment from the acoustic point.

4.110 Location No. 11 in Figure 386-1/31 Vibratory Cleaner

Compensation scale	A	B	C	L
Maximum levels, db	94	97	99	99
Minimum levels, db	93	96	98	98

Octave Band Analysis /13

Band level

Center frequency, Hz	Maxima	Minima
31.5	88	87
63	93	92
125	92	91
250	92	91
500	90	89
1,000	89	88
2,000	87	86
4,000	85	84
8,000	80	79
16,000	72	71
31,500	53	52

Figure 386-11/31 shows the octave-band spectrum. Note that the 85 db curve is exceeded between 125 Hz and 4 KHz which shows that the noise at that location is excessive within the intelligible band thereby substantiating the observations made in 4.70. Figure 386-24/31 shows the percentage band spectrum of the noise that was observed.

4.120 Location No. 12 in Figure 386-1/31 Vibratory Cleaner/Cleaner

Compensation scale	A	B	C	L
Maximum levels, db	91	94	98	99
Minimum levels, db	90	93	97	97

Octave Band Analysis

Center frequency, Hz	Band level Maxima	Band level Minima
31.5	87	86
63	94	93
125	91	90
250	92	91
500	88	87
1,000	85	84
2,000	83	82
4,000	83	82
8,000	75	74
16,000	59	58
31,500	42	41

/14

Figure 386-12/31 shows the octave band spectrum. Note that, in addition to the overall level exceeding the allowed maximum, the 85 db curve is exceeded between 125 Hz and 1 KHz. Figure 386-28/31 shows the percentage band spectrum for the noise observed.

4.130 Location No. 13 in Figure 386-1/31 Vibratory Track

Compensation scale	A	B	C	L
Maximum levels, db	96	98	101	102
Minimum levels, db	95	97	100	101

Octave Band Analysis

Center frequency, Hz	Band level Maxima	Minima
31.5	87	86
63	89	88
125	90	89
250	92	91
500	92	91
1,000	93	92
2,000	93	92
4,000	90	89
8,000	84	83
16,000	75	74
31,500	50	49

Figure 386-13/31 shows the octave-band spectrum. Note that the 85 db curve is exceeded between 125 Hz and 4 KHz which renders the environment annoying and obscures the intelligibility range. The observations expressed in 4.70 /15 are applicable here.

4.140 Location #14 in Figure 386-1/31 Furnaces

Compensation scale	A	B	C	L
Maximum levels, db	96	97	98	100
Minimum levels, db	95	96	97	99

Octave Band Analysis

Center frequency, Hz	Band level Maxima	Minima
31.5	87	86
63	100	99

Center frequency, Hz	Maxima	Minima
125	100	99
250	101	100
500		

Center frequency, Hz	Maxima	Minima
125	101	100
250	90	89
500	90	89
1,000	92	91
2,000	91	90
4,000	83	82
8,000	79	78
16,000	72	71
31,500	66	65

Figure 386-14/31 shows the octave-band spectrum. Note that the 85 db curve is exceeded between 63 Hz and 4 KHz. The considerations in 4.70 apply with respect to the adverse effects on intelligibility.

4.150 Location No. 15 in Figure 386-1/31 Shakeout

Compensation scale	A	B	C	L
Maximum levels, db	98	99	103	102
Minimum levels, db	97	98	102	101

Octave Band Analysis /16

Band level

Center frequency, Hz	Maxima	Minima
31.5	90	89
63	93	92
125	94	93
250	92	91
500	92	91
1,000	94	93

Center frequency, Hz	Maxima	Minima
2,000	90	89
4,000	88	87
8,000	84	83
16,000	76	75
31,500	65	64

Figure 386-15/31 shows the octave-band spectrum. Note that the 85 db curve is exceeded between 125 Hz and 5 KHz which adversely affects intelligibility. The observations made in 4.70 apply. Figure 386-26/31 shows the percentage band spectrum.

4.160 Location #16 in Figure 386-1/31 Coring-Compressed Air [illegible] Machine

Compensation scale	A	B	C	L
Maximum levels, db	92	91	94	94
Minimum levels, db	91	90	93	93

Octave Band Analysis

Band level

Center frequency, Hz	Maxima	Minima
31.5	83	82
63	81	82
125	81	80
250	84	83
500	86	85
1,000	87	86
2,000	83	82
4,000	77	76
8,000	75	74
16,000	73	72
31,500	55	54

/17

Figure 386-16/31 shows the octave-band spectrum. Note that the 85 db curve is exceeded only between 500 Kz and 2 KHz. There is some annoyance since

the curve is exceeded and since the overall level is above the maximum allowable. Figure 386-26/31 shows the percentage-band spectrum for the noise observed.

4.170 Location No. 17 in Figure 386-1/31 Compressor Room

Compensation scale	A	B	C	L
Maximum levels, db	94	102	107	108.5
Minimum levels, db	93	101	106	108

Octave Band Analysis

Center frequency, Hz	Band level Maxima	Minima
31.5	100	90
63	107	106
125	101	100
250	91	90
500	88	87
1,000	88.5	87.5
2,000	86	85.5
4,000	83	82
8,000	77	76
16,000	66	65
31,500	44	43

Figure 386-17/31 shows the octave-band spectrum. Note the spectrum curve exceeds the 85 db curve between 40 Hz and 2.5 KHz. This creates an environment /18 that is highly adverse to intelligibility (hence the considerations in 4.70 apply) as well as quite annoying since the existing levels can cause a worker to lose his hearing after brief and daily exposure to this environment. If this does not happen, quite probably it is because either the worker already has a considerable hearing loss or he has been in that location for only a short while. In this case, it is most imperative that immediate steps are taken. Figure 386-27/31 shows the percent band spectrum. Note that there is a high intensity of components in the low frequency range which contributes to making

the environment disagreeable and annoying. Measurements and analyses were also made of the acceleration of the motors and compressor which will be discussed later.

4.180 Location No. 18 in Figure 386-1/31 Mixer-Casting

Compensation scale	A	B	C	L
Maximum levels, db	97	98	99	99
Minimum levels, db	96	97	98	98

Octave Band Analysis

Center frequency, Hz	Band level Maxima	Minima
31.5	89	88
63	89	88
125	87	86
250	88	87
500	87	86
1,000	90	89
2,000	89	88
4,000	86	85
8,000	82	81
16,000	80	79
31,500	56	55

Figure 386-18/31 shows the octave-band spectrum. Note that the 85 db /19
curve is exceeded between 500 Hz and 4 KHz and that the overall level is above that considered acceptable.

4.190 Location No. 19 in Figure 386-1/31 Air Intakes in the Scrap Yard

Compensation scale	A	B	C	L
Maximum levels, db	100	105	106.5	107
Minimum levels, db	99	104	105.5	106

	Octave Band Analysis Band level		
Center frequency, Hz	Maxima		Minima
31.5	95	94	94
63	101		100
125	99		98
250	103		102
500	97		96
1,000	91		92
2,000	86		85
4,000	83		82
8,000	76		75
16,000	66		65
31,000	46		45

Figure 386-19/31 shows the octave-band spectrum. Note that the 85 db curve is exceeded by high levels, between 63 Hz and 2 KHz. In view of a sound level of 105 db throughout the entire working day, workers should not remain in such a location. A normal worker who spends his entire working day, every day in this environment will certainly become deaf after one or two years. The maximum allowable period for exposure to such levels is 30 minutes per day for /20
individuals under 30 years of age. The maximum for individuals between age 50 and 60 is 8 minutes per day. Greater exposure produces permanent deafness in a short time.

4.200 Location No. 20 in Figure 386-1/31 Emery Grinders in the Yard

Compensation scale	A	B	C	L
Maximum levels, db	102	103	104	104
Minimum levels, db	101	102	102	103

	Octave Band Analysis Band level	
Center frequency, Hz	Maxima	Minima
31.5	93	92
63	95	94

Center frequency, Hz	Maxima	Minima
125	94	93
250	93	92
500	93	92
1,000	92	91
2,000	90	89
4,000	90	89
8,000	92	91
16,000	89	88
31,500	58	57

Figure 386-20/31 shows the octave-band spectrum. Note that the 85 db curve is exceeded between 90 Hz and 8.2 KHz, that is, practically the entire audio, intelligibility and injury to hearing range. Working under such conditions, the observations noted in 4.70 are appropriate to this case as well as are those noted in 4.190 above. There is extensive annoyance to and changes to the auditory system of a person working in such a location.

5.00 Considerations on the Sound Levels /21

The measurements and analyses that were made show that industrial plants are operating under conditions that are highly injurious to the hearing of the workers and that urgent steps must be taken to reduce the current levels to internationally acceptable values. It is true that legislation is lacking in Brazil because there are no specialists in the field. This results in regulation by individuals who have good intentions but who are poorly informed. Thus, there is a need for a foundation based on existing publications in the specialized literature, where the levels found in the FOZ plant are completely condemned. Quite possibly, regulation may become modified in such a way that it will result in problems of workmen's compensation, relief claims, and work schedules which will place any industry in a delicate situation. Since, throughout the country, the industrial plants are growing in a disorderly manner and unless the necessary steps are taken to promote harmonious developments, the problem of industrial noise has reached such a point that an immediate or short

short range solution is impractical not only because of financial reasons but also technical reasons since the available data on the problem is scarce and rare. The few available facts deal with recording of noise levels, generally done with inadequate instruments and without the calibration which the case requires.

With respect to Conexoes de Ferro Foz S/A, the problem can be resolved only by long-range measures provided new plants and expansion are accomplished in accordance with a procedure that studies every aspect and is guided by steps which must be taken to avoid aggravating the problem and even to creating new sources of noise. The present plants will have to be modified over a long term. Each piece of equipment, machine or equipment group must be attenuated. At the earliest opportunity, FOZ will receive a proposed project designed to attenuate sound levels and will also be informed of the procedure to be adopted in order to avoid aggravating the problem in the future. /22

6.00 Observations Concerning the Motors and Compressors

During the first fact-finding visit, it was noted that one of the electric motors that drives the compressors, more specifically, the motor which drives the Atlas-Cepco compressor exhibited an unusual amount of vibration. A detailed study was made of that motor and compressor as well as a second compressor which did not pose the same problem. Figures 386-29/31 and 386/30/31 show the percentage band spectrum of the vibrations and displacement of the moving parts of the motor in question and Figure 386-31/31, the upper percentage spectrum of the compressor. Figure 386-31/31 shows the acceleration in percentage band of the motor which exhibits no excessive vibration. One notes immediately that, by simple comparison, between the range of 20 and 63 Hz motor No. 3 has an acceleration peak at 30 Hz which corresponds to the motor's revolution. Such a peak does not occur with Motor No. 1. The displacement curve, Figure 386--30/31 shows that this peak is the result of an excessive allowance in the motor's bearings since this vibration was not detected in the compressor, and since it was possible to locate its source. Since it was not possible to stop the motor in order to check the diameter of its shaft precisely, we do not

possess data to check exactly what the gap was. In any case, the maximum allowance permitted by the bearing, in terms of diameter, is provided in the following formula:

$$\delta r < 1/2\ 0{\cdot}25{\cdot}10^{-3}\ \text{mm}$$

and the maximum eccentricity must be limited to /23

$$\Delta e < 25{\cdot}10^{-4}\ \text{mm}.$$

The measurements that were taken show that the eccentricity is quite above that permitted as an extreme value. Should the motor continue to be operated under present conditions, very likely there will be breakdown and rapid replacement problems and it is easy to foresee consequences affecting plant production. We recommend that immediate steps be taken to replace the bearings on the motor before replacement has to be made when in full operation and possibly, without the bearing being in stock, by an exchange at the time.

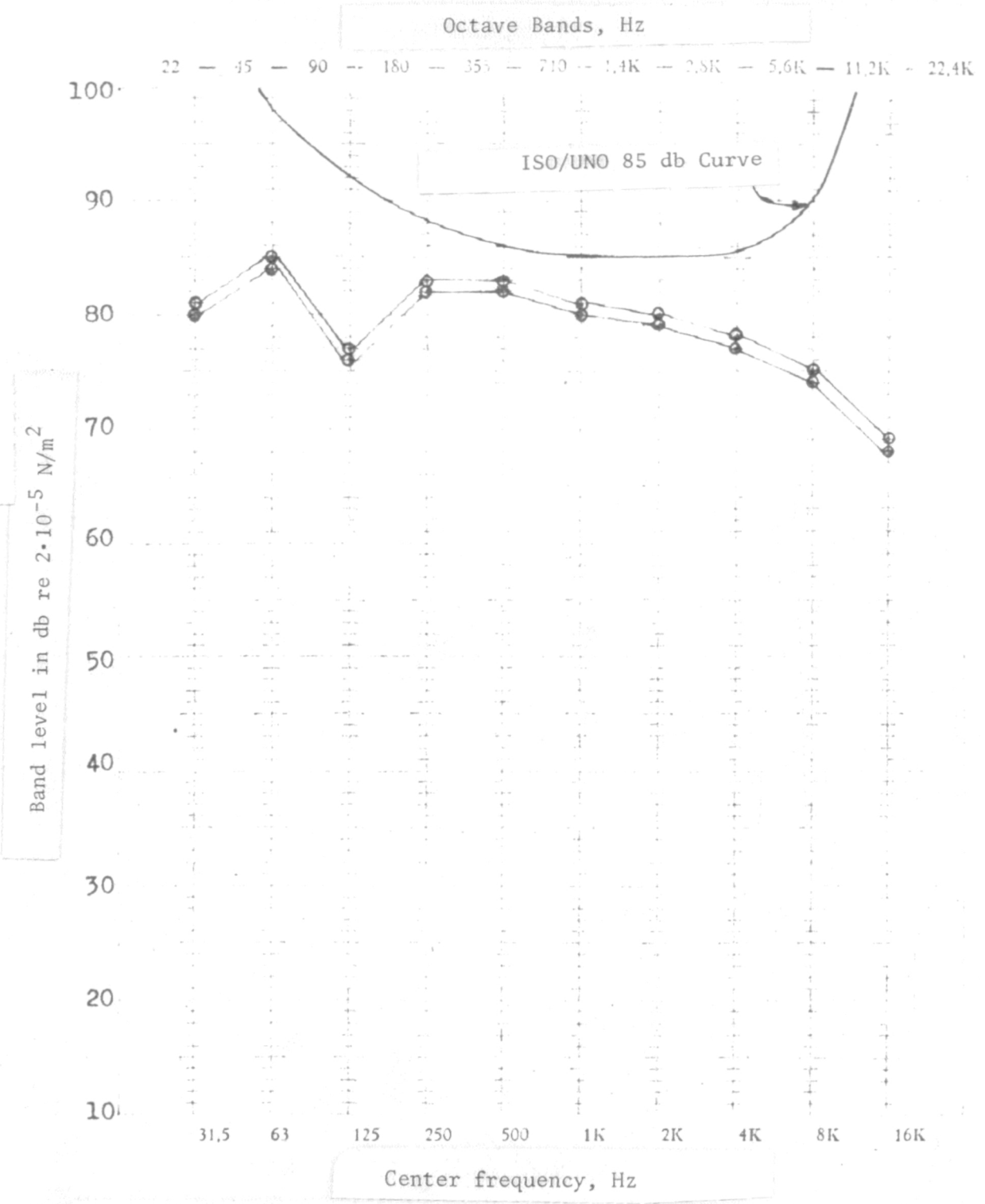
Sao Paulo, 10 October 1969

Measurements and analysis performed by L. F. B. Delbonne, J. R. da Costa and E. J. Cury.

REFERENCES

1. Rosenblith and Stevens, "Handbook of Acoustic Noise Control," Vols. I and II, Office of Technical Services, Washington, D. C. 1953.
2. Harris, "Handbook of Noise Control," John Wiley & Sons, New York, 1957.
3. Nepomuceno, *Tecnicas de Medidas de Barulho Industrial Engenharia*, Vol. 28, pp. 620-624, 1960.
4. Baron, "Relative General Rules for Measuring Machine Noise," Proposition for the 8th Working Group of ISO/TC-43, Paris, March 1960.
5. Harris and Crede, "Handbook of Shock and Vibration," McGraw-Hill Press, New York, 1962. /5
6. Beranek, "Acoustic Measurements," John Wiley & Sons, New York, 1949.
7. Siemens-Schuckertwerke, "Noise Measurements," Std. No. SSW-282-01/ /01.01, Berlin, Siemensstadt
8. Beranek, "Noise Reduction Theory and Practice," John Wiley & Sons, New York, 1962.
9. Nepomuceno, *Acustica Tecnica* [Technical Acoustics], Editora Tecnico Grafica Ltda., 1968.
10. Klotter, *Technische Schwingungslehre* [Technical Vibrations Theory], Springer Press, Berlin, 1951.

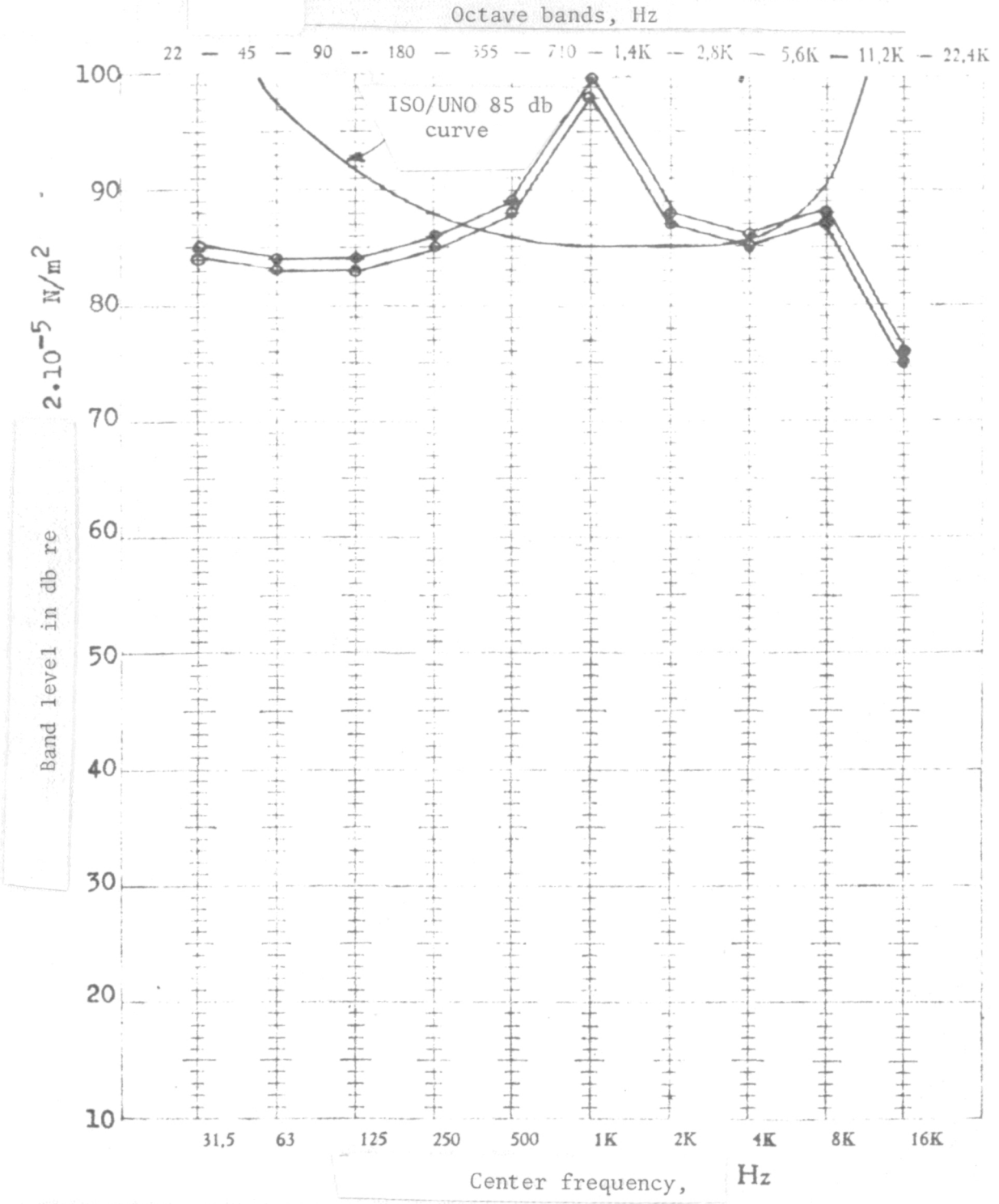
Translated for the National Aeronautics and Space Administration under contract No. NASw-2037 by Techtran Corporation, P. O. Box 729, Glen Burnie, Maryland 21061.



Measurements taken at Location No. 1 indicated on Figure 386-1/31.

Compensation scale	A	B	C	L
Maximum levels, db	88	91	89	91
Minimum levels, db	87	90	88	90

ACÚSTICA SÔNICA	LABORATÓRIO DE ACÚSTICA E SÔNICA S/C/L — C. P. 12.946 R. Esmeralda, 149 - S. Paulo	DATA 601010 NÚMERO 386-2/31	CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 2 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum levels, db	98	98	99	99
Minimum levels, db	97	97	98	98

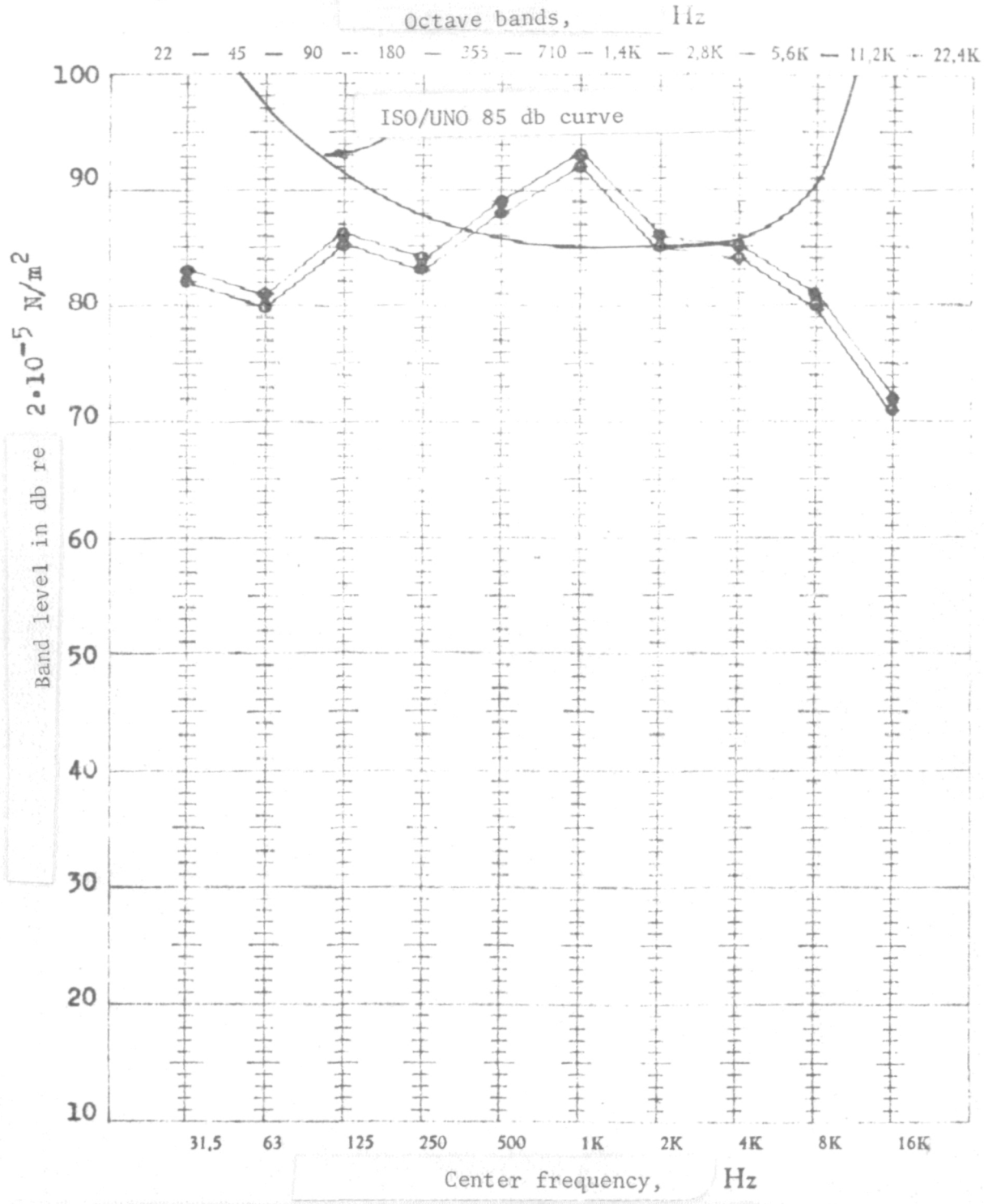
ACÚSTICA SÔNICA

LABORATÓRIO DE ACÚSTICA E SÔNICA
S/C/L — C. P. 12.946
R. Esmeralda, 149 - S. Paulo

DATA 691010

NÚMERO 386-3/31

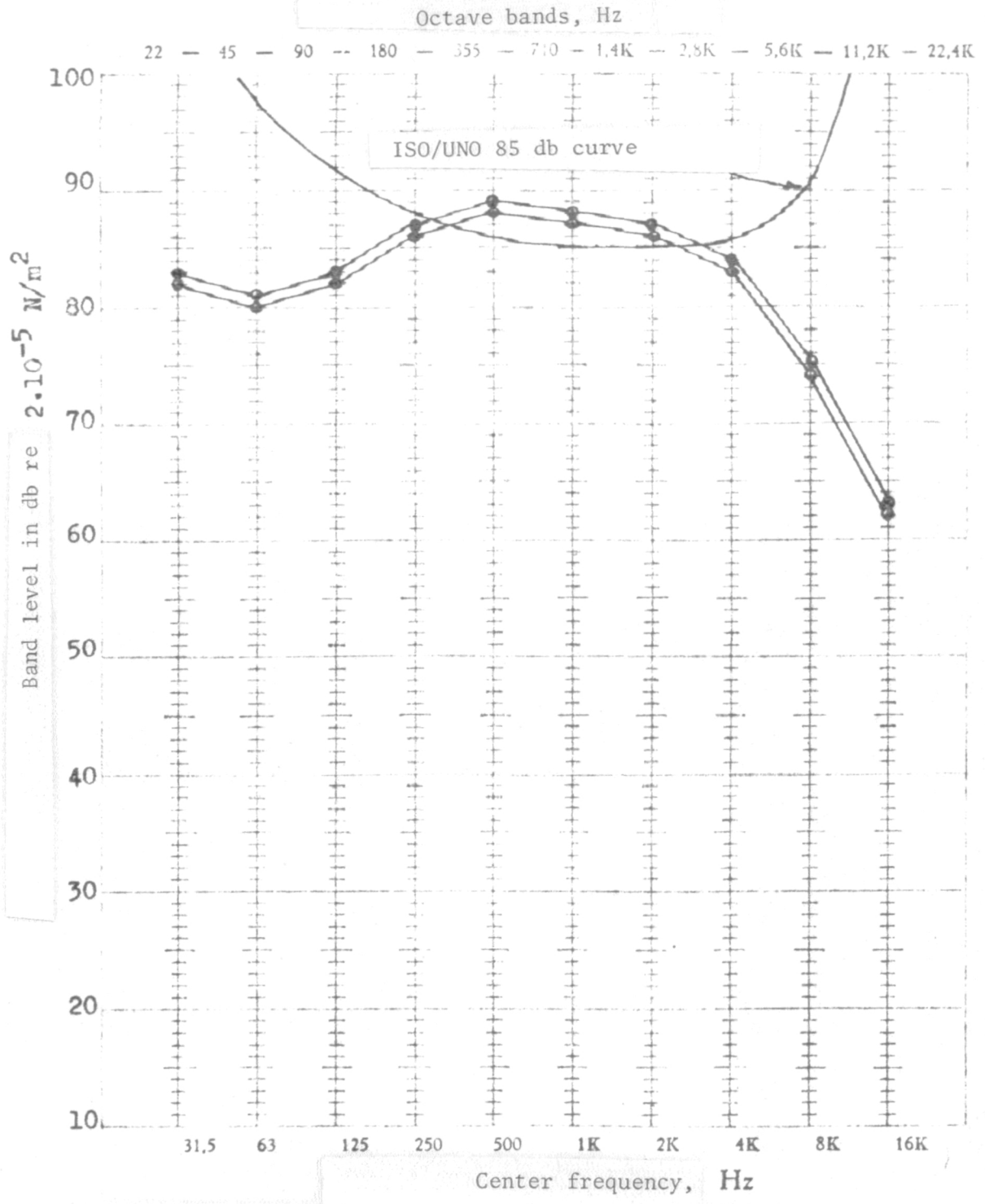
CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 3 indicated on Figure 386-1/31

Compensation scale:	A	B	C	L
Maximum levels, db	96	97	98	99
Minimum levels, db	95	96	97	98

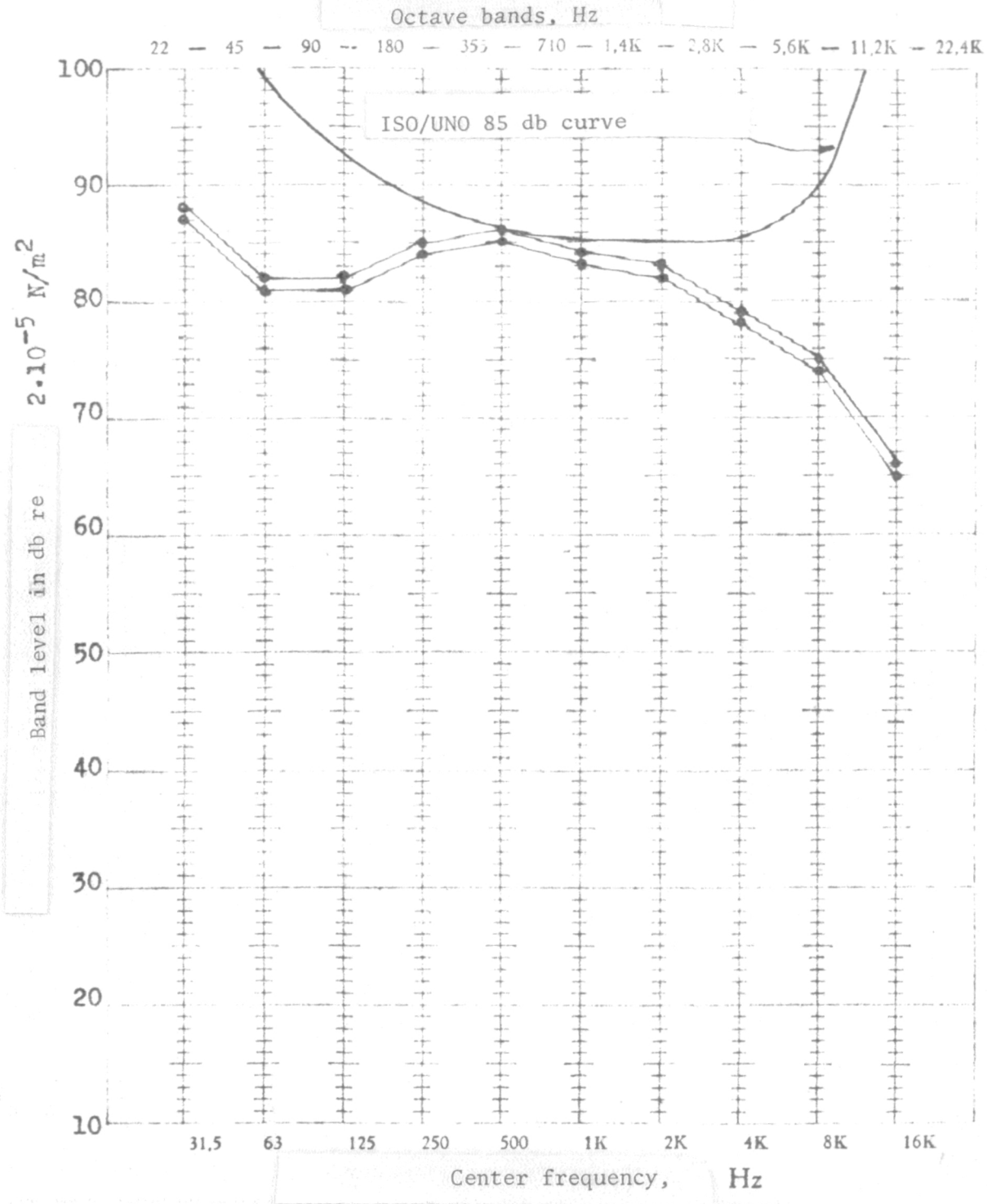
ACÚSTICA SÔNICA	LABORATÓRIO DE ACÚSTICA E SÔNICA S/C/L — C. P. 12.946 R. Esmeralda, 149 - S. Paulo	DATA 691010 NÚMERO 386-4/31	CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 4 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum levels, db	92	94	96	97
Minimum levels, db	91	93	95	96

ACÚSTICA SÔNICA	LABORATÓRIO DE ACÚSTICA E SÔNICA S/C/L — C. P. 12.946 R. Esmeralda, 149 - S. Paulo	DATA 691010 NÚMERO 386-5/31	CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 5 indicated on Figure 386-1/31

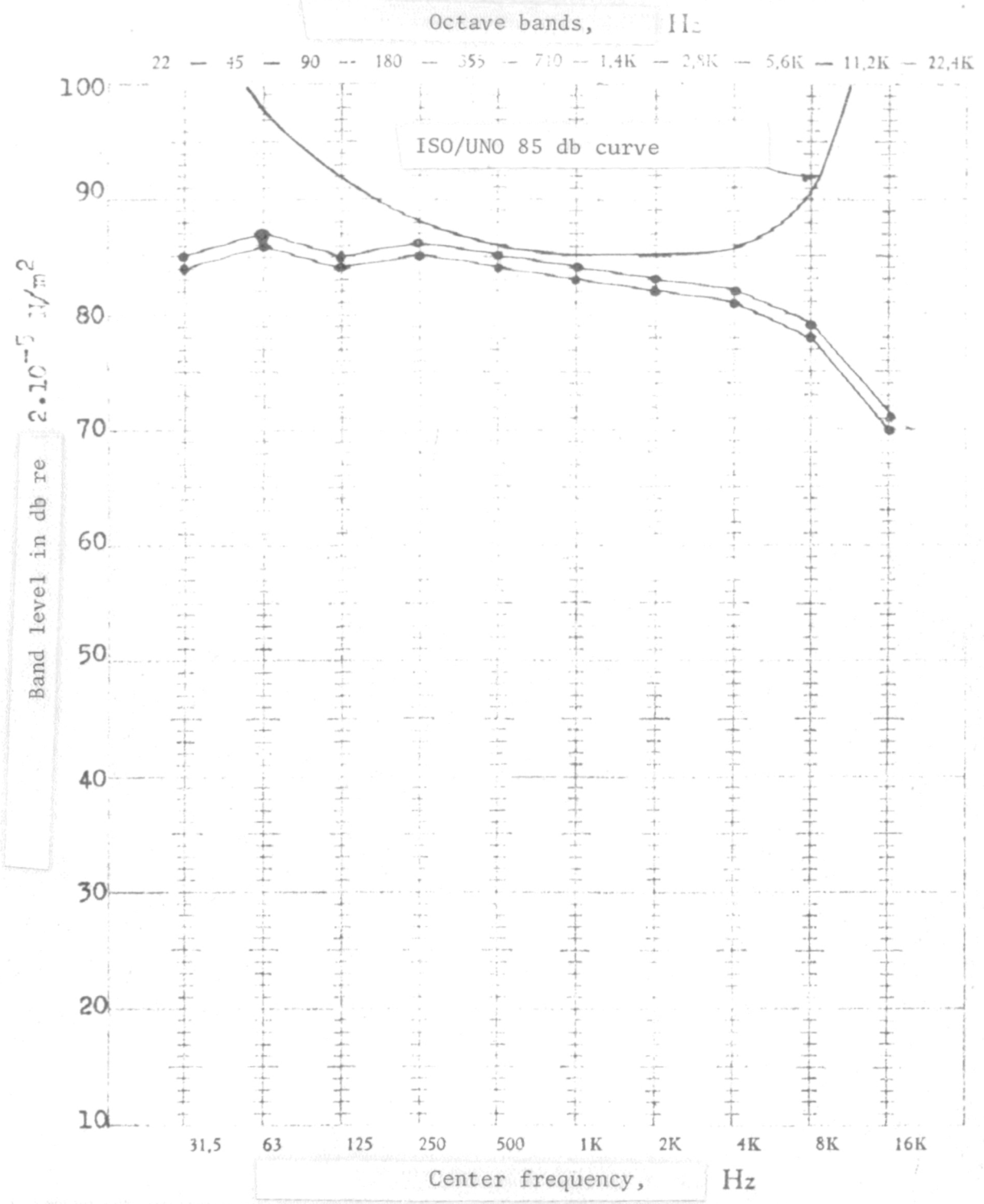
Compensation scale	A	B	C	L
Maximum levels, db	89	90	92	94
Minimum levels, db	88	89	91	92

ACÚSTICA SÔNICA
LABORATÓRIO DE ACÚSTICA E SÔNICA
S/C/L — C. P. 12.946
R. Esmeralda, 149 - S. Paulo

DATA 691010

NÚMERO 386-6/31

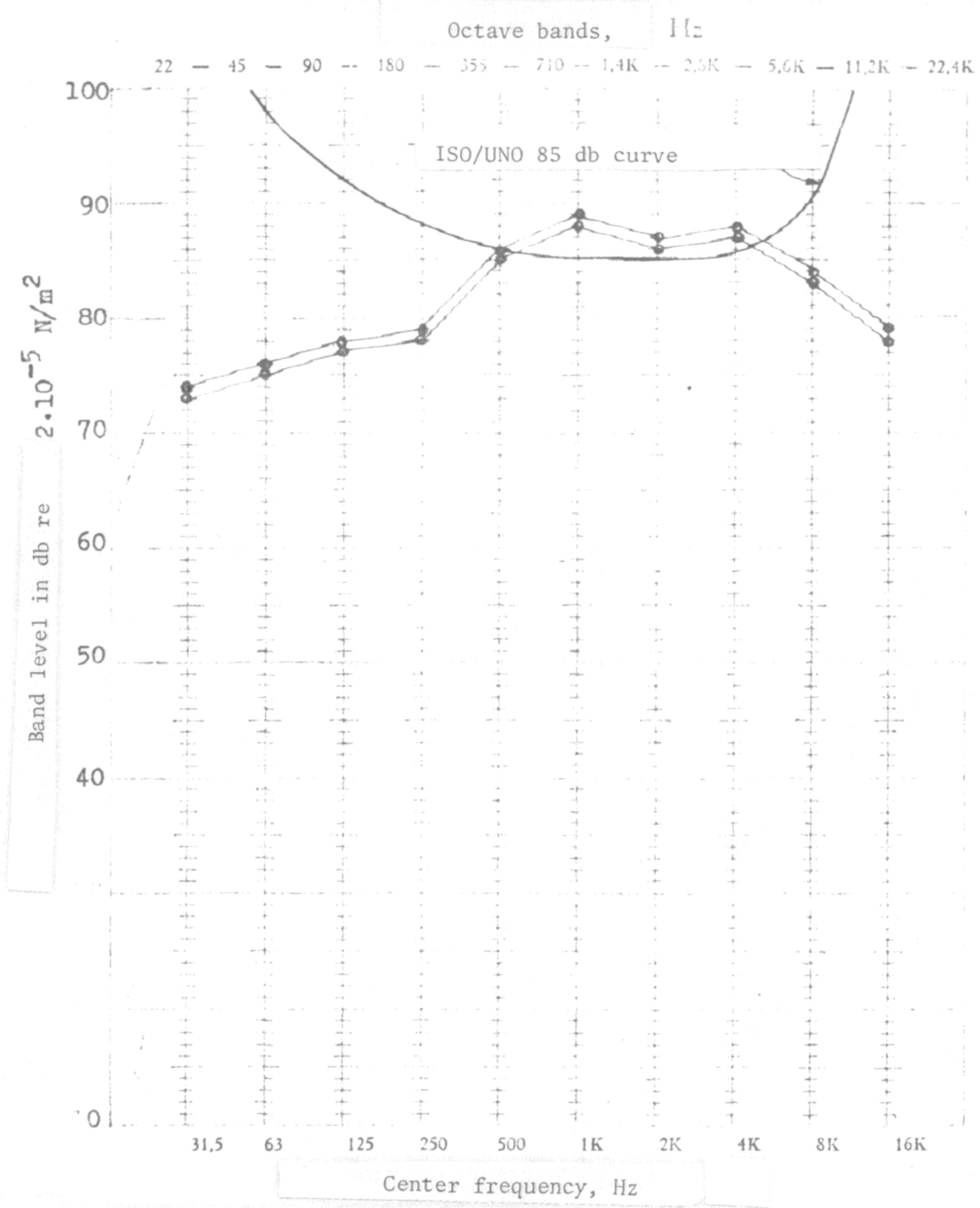
CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 6 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum levels, db	91	93	94	95
Minimum levels, db	90	92	93	94

ACÚSTICA SÔNICA	LABORATÓRIO DE ACÚSTICA E SÔNICA S/C/L — C. P. 12.946 R. Esmeralda, 149 - S. Paulo	DATA 691010 NÚMERO 386- 7/31	CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 8 indicated on Figure 386-1/31

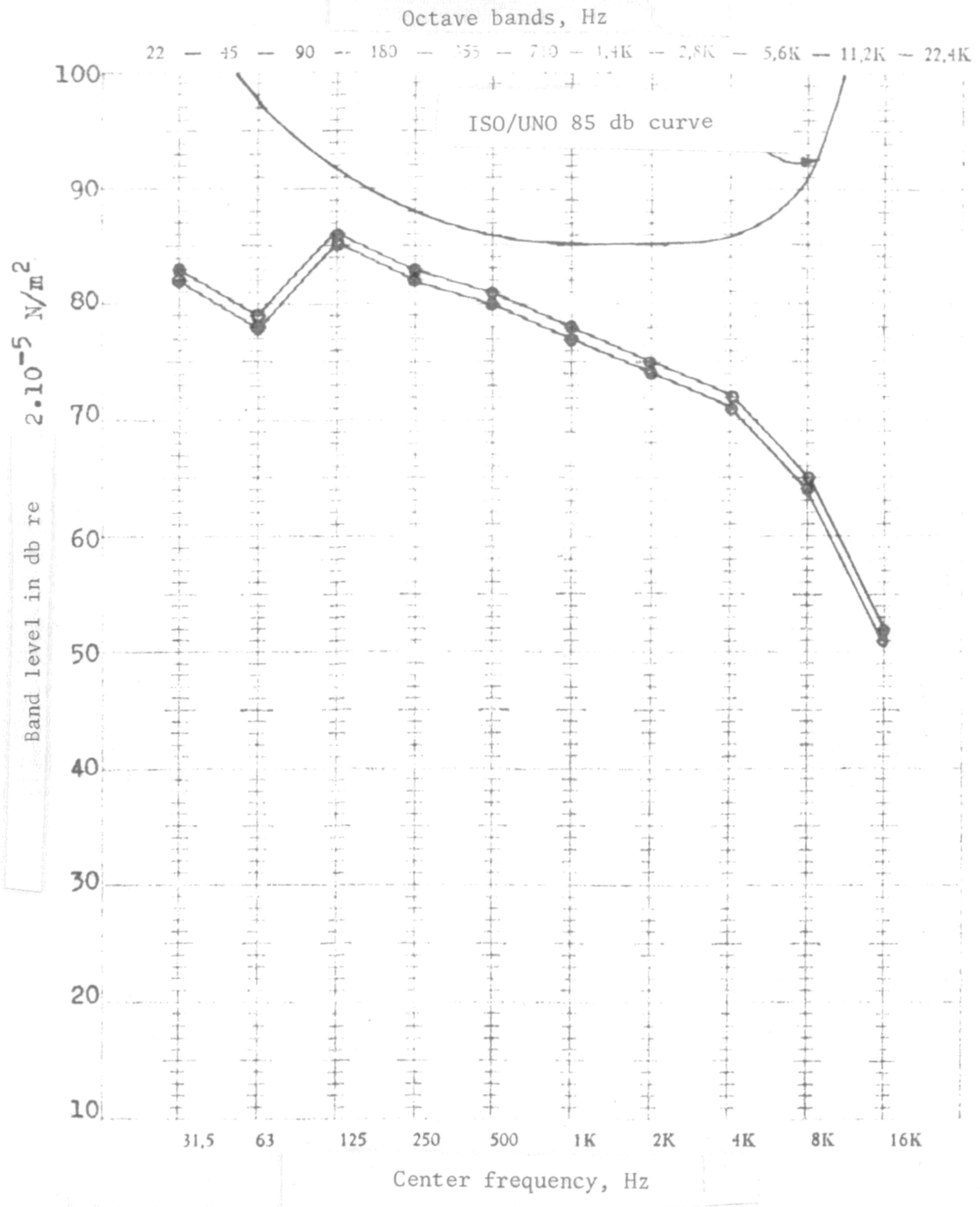
Compensation scale	A	B	C	L
Maximum levels, db	95	95	95,5	96
Minimum levels, db	94	94	94,5	95

ACÚSTICA SÔNICA
LABORATÓRIO DE ACÚSTICA E SÔNICA
S/C/L — C. P. 12.946
R. Esmeralda, 149 - S. Paulo

DATA 691010

NÚMERO 386- 8/31

CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 9 indicated on Figure 386-1/31

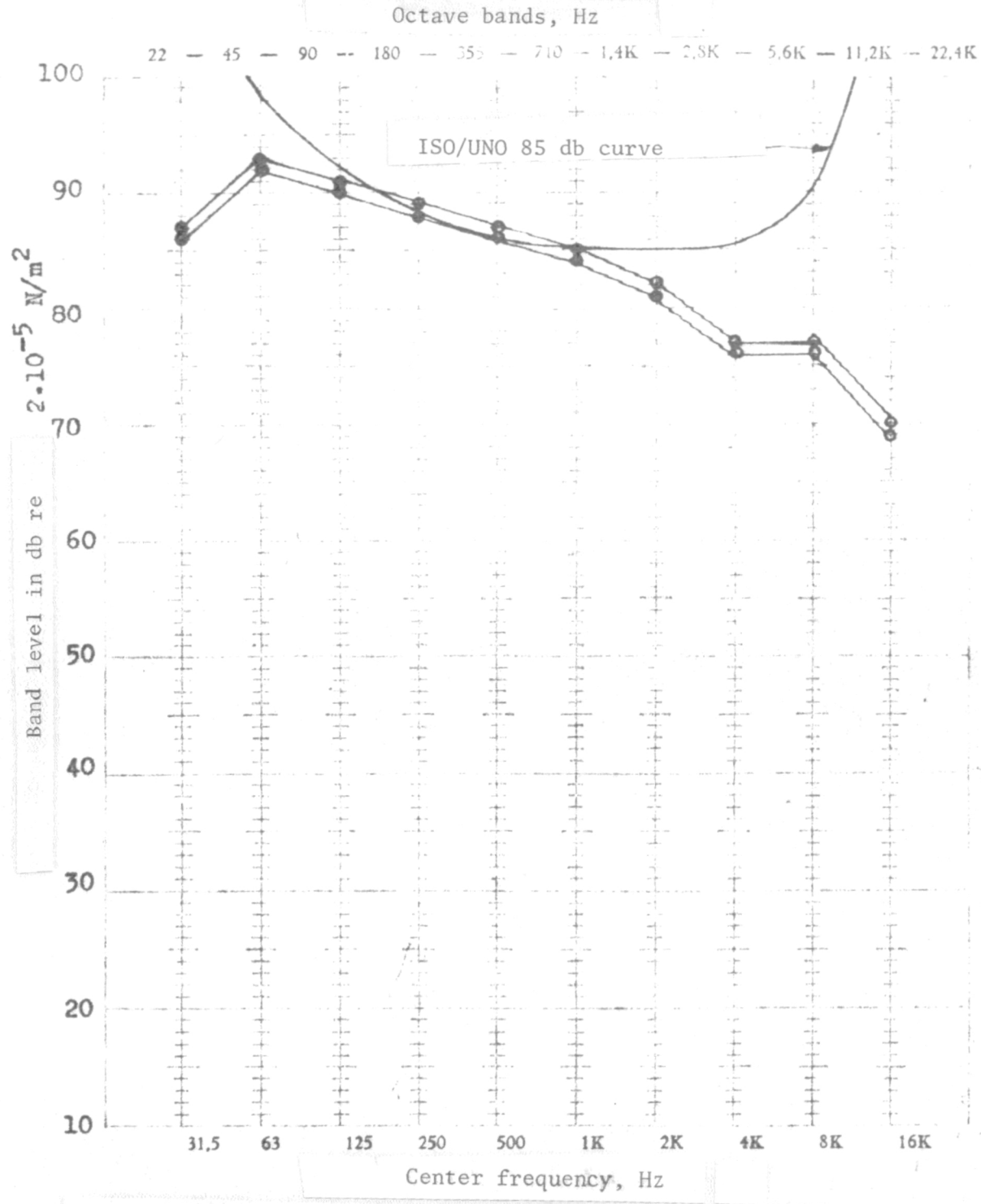
Compensation scale	A	B	C	L
Maximum levels, db	88	91	92	94
Minimum levels, db	87	90	91	93

ACÚSTICA SÔNICA
LABORATÓRIO DE ACÚSTICA E SÔNICA
S/C/L — C. P. 12.946
R. Esmeralda, 149 - S. Paulo

DATA 691010

NÚMERO 386-9/31

CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 10 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum levels, db	91	93	95	97
Minimum levels, db	90	92	94	96

ACÚSTICA SÔNICA
LABORATÓRIO DE ACÚSTICA E SÔNICA
S/C/L — C. P. 12.946
R. Esmeralda, 149 - S. Paulo

DATA 691010

NÚMERO 386-10/31

CONEXÕES DE FERRO FOZ S/A

Lower yard

Finishing

.19

.20

Coring

.16

N°2

.15

.14

N°3

Molding Line

.18 N°1

.12

.8

.4

.2

.6

Machining

.11

.9

.3

Fettling

.10

Annealing

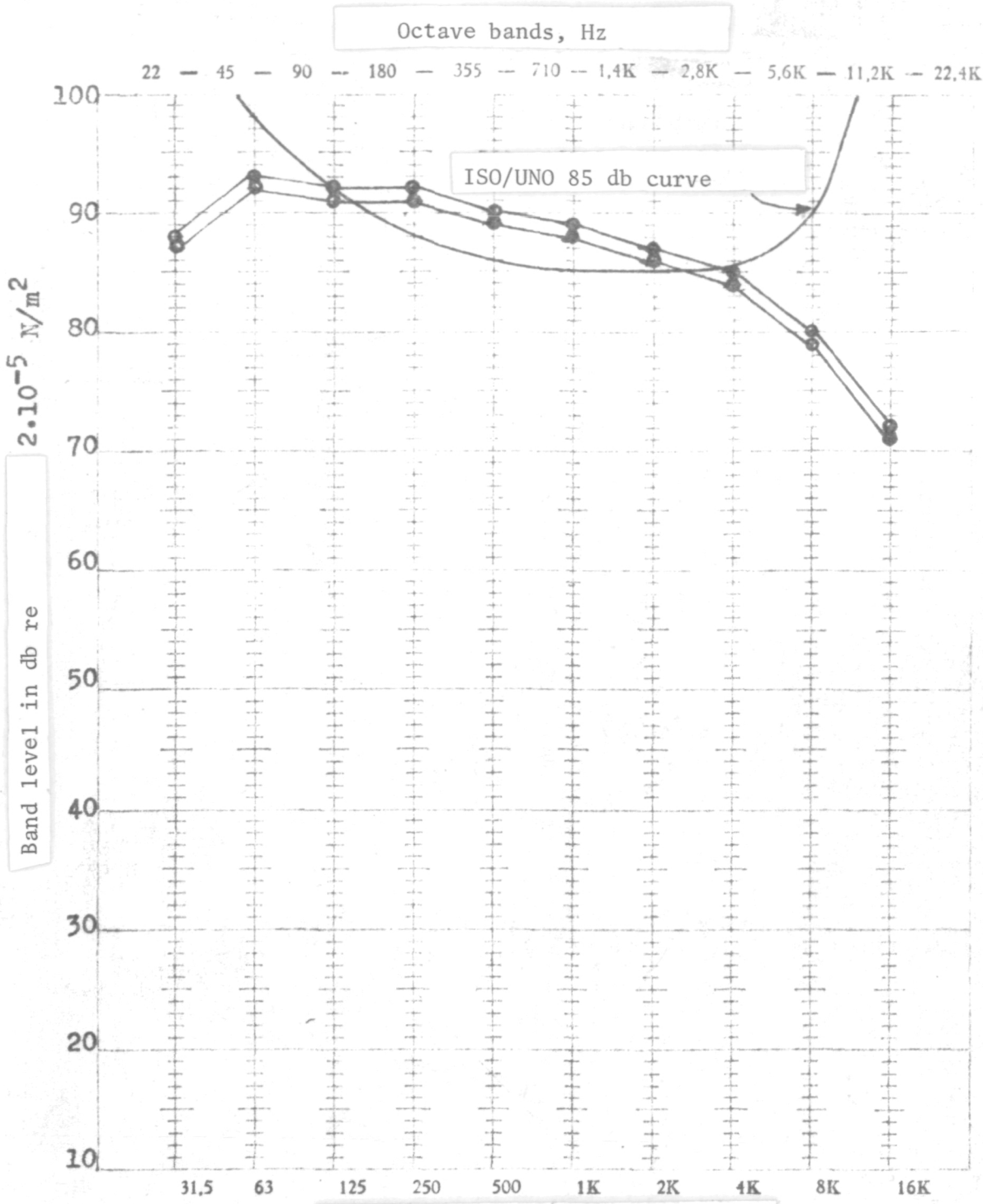
Tool shop

.1

Machine room

.17

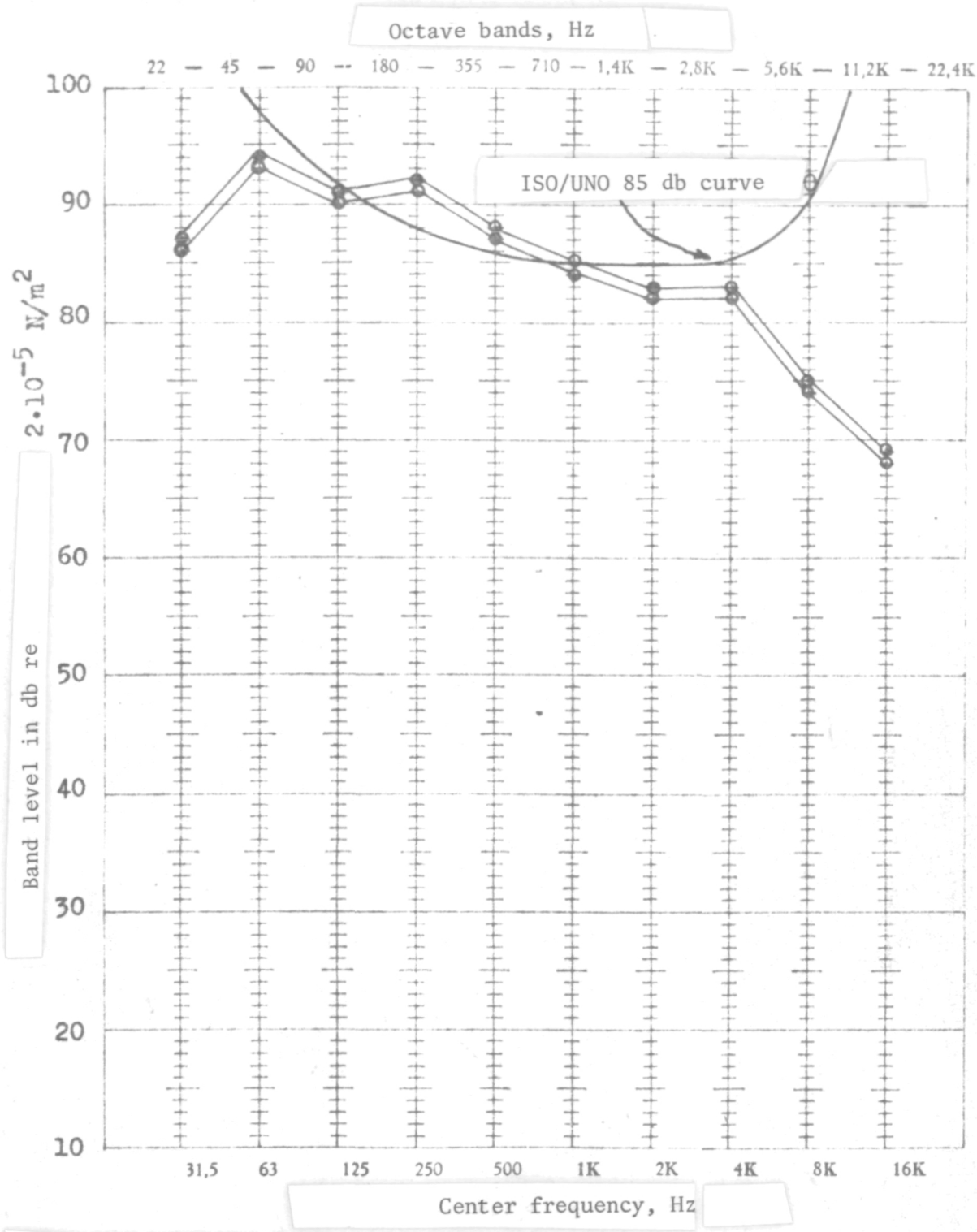
386-1/31



Measurements taken at location No. 11 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum overall levels, db	94	97	99	99
Minimum overall levels, db	93	96	98	98

ACÚSTICA SÔNICA	LABORATÓRIO DE ACÚSTICA E SÔNICA S/C/L — C. P. 12.946 R. Esmeralda, 149 - S. Paulo	DATA 691010 NÚMERO 386-11/31	CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 12 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum levels, db	91	94	98	99
Minimum levels, db	90	93	97	97

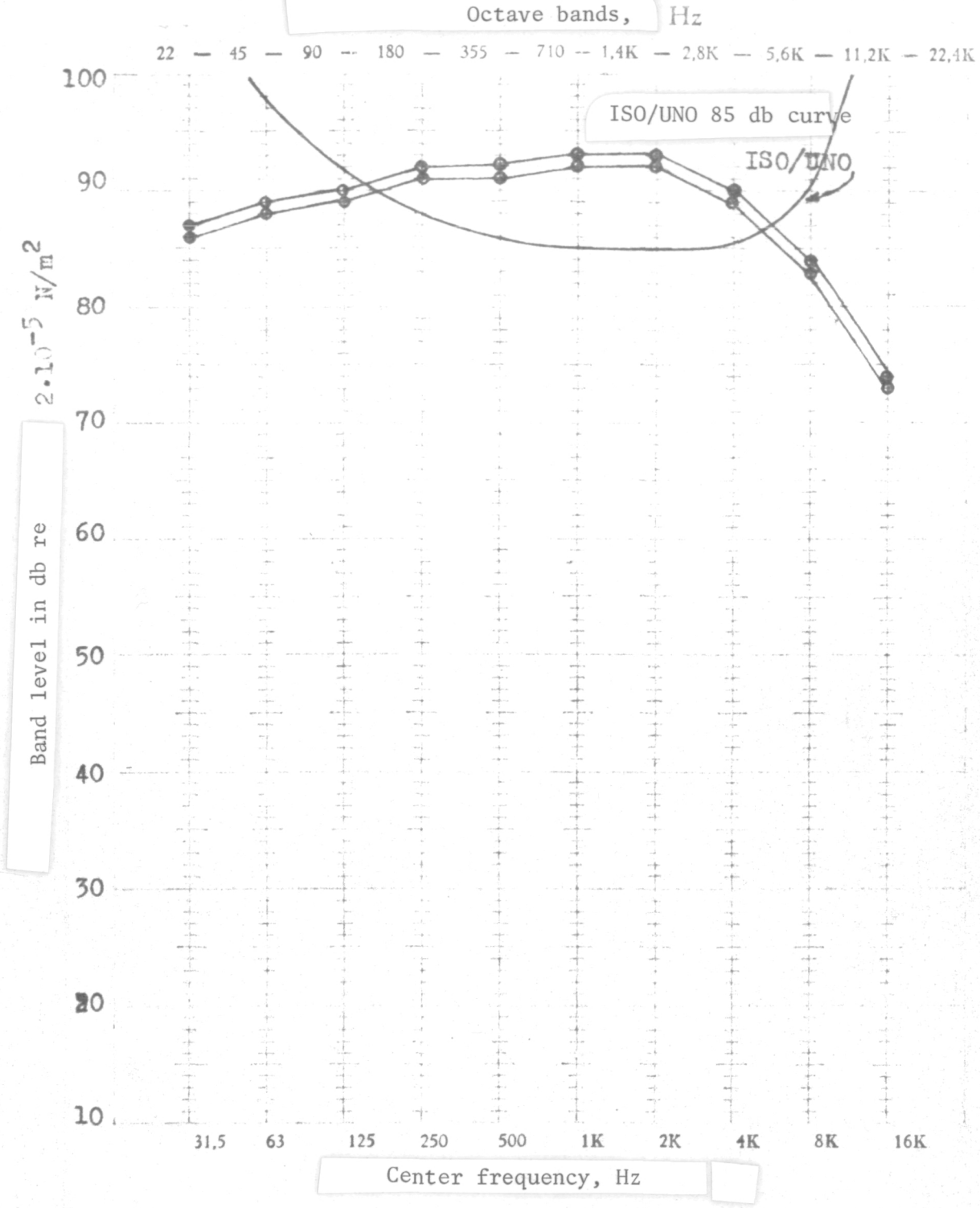
ACÚSTICA SÔNICA

LABORATÓRIO DE ACÚSTICA E SÔNICA
S/C/L — C. P. 12.946
R. Esmeralda, 149 - S. Paulo

DATA
01010

NUMERO
386-12/31

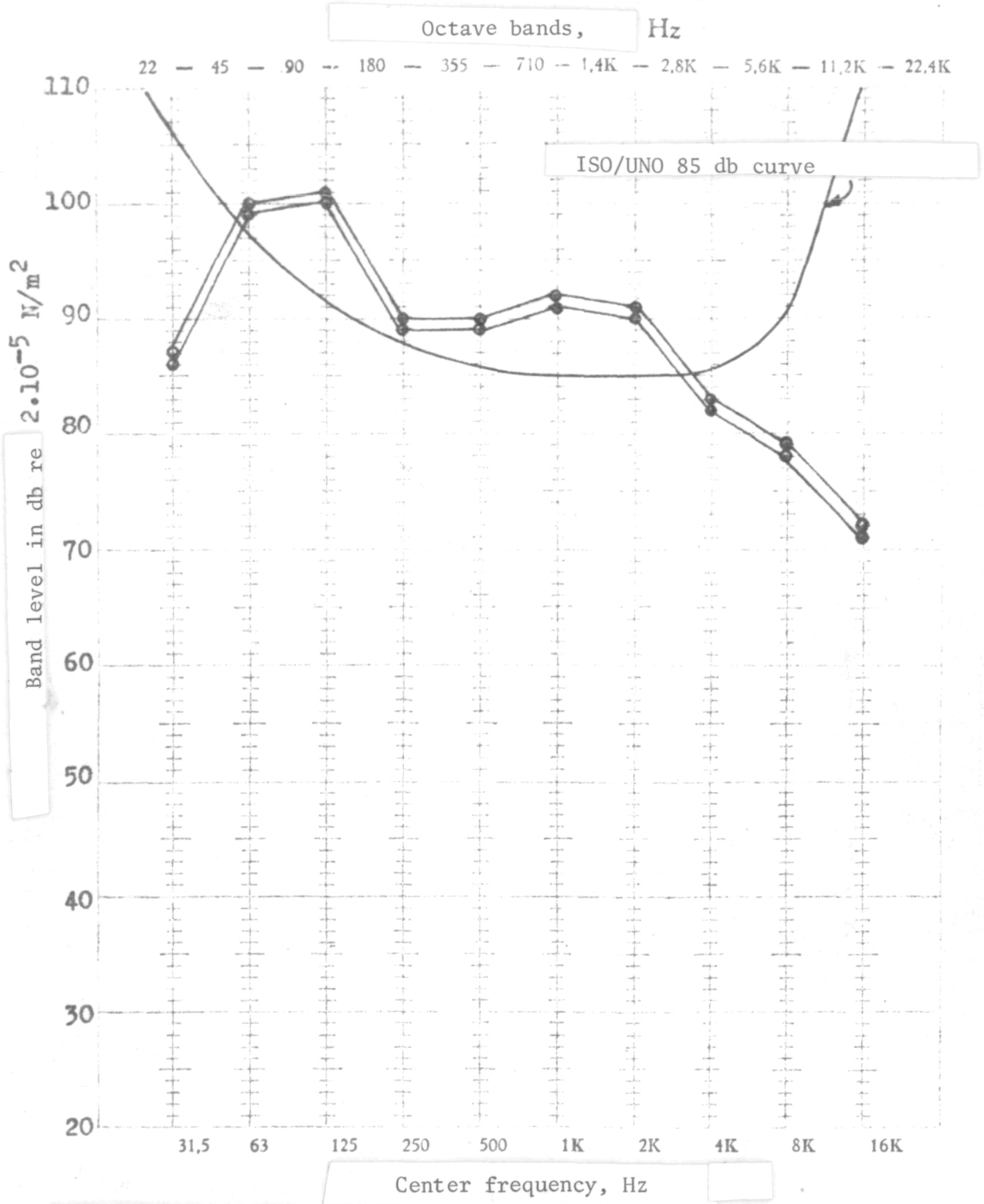
CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 13 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum levels, db	96	98	101	102
Minimum levels, db	95	97	100	101

ACÚSTICA SÔNICA	LABORATÓRIO DE ACÚSTICA E SÔNICA S/C/L — C. P. 12.946 R. Esmeralda, 149 - S. Paulo	DATA 691010 NÚMERO 386-13/31	CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 14 indicated on Figure 386-1/31

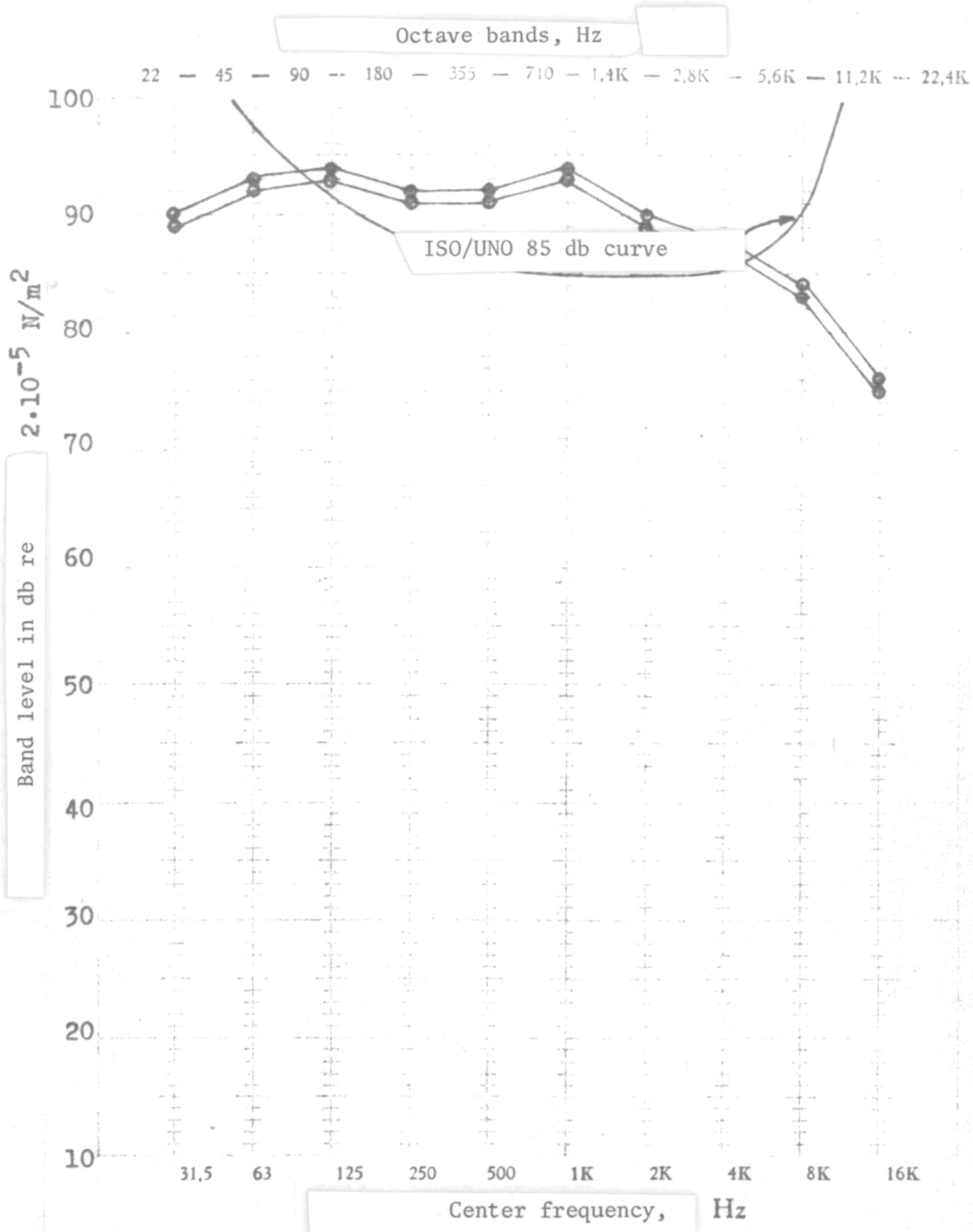
Compensation scale	A	B	C	L
Maximum overall levels, db	96	97	98	100
Minimum overall levels, db	95	96	97	99

ACÚSTICA SÔNICA
LABORATÓRIO DE ACÚSTICA E SÔNICA
S/C/L — C. P. 12.946
R. Esmeralda, 149 - S. Paulo

DATA 691010

NÚMERO 386-14/31

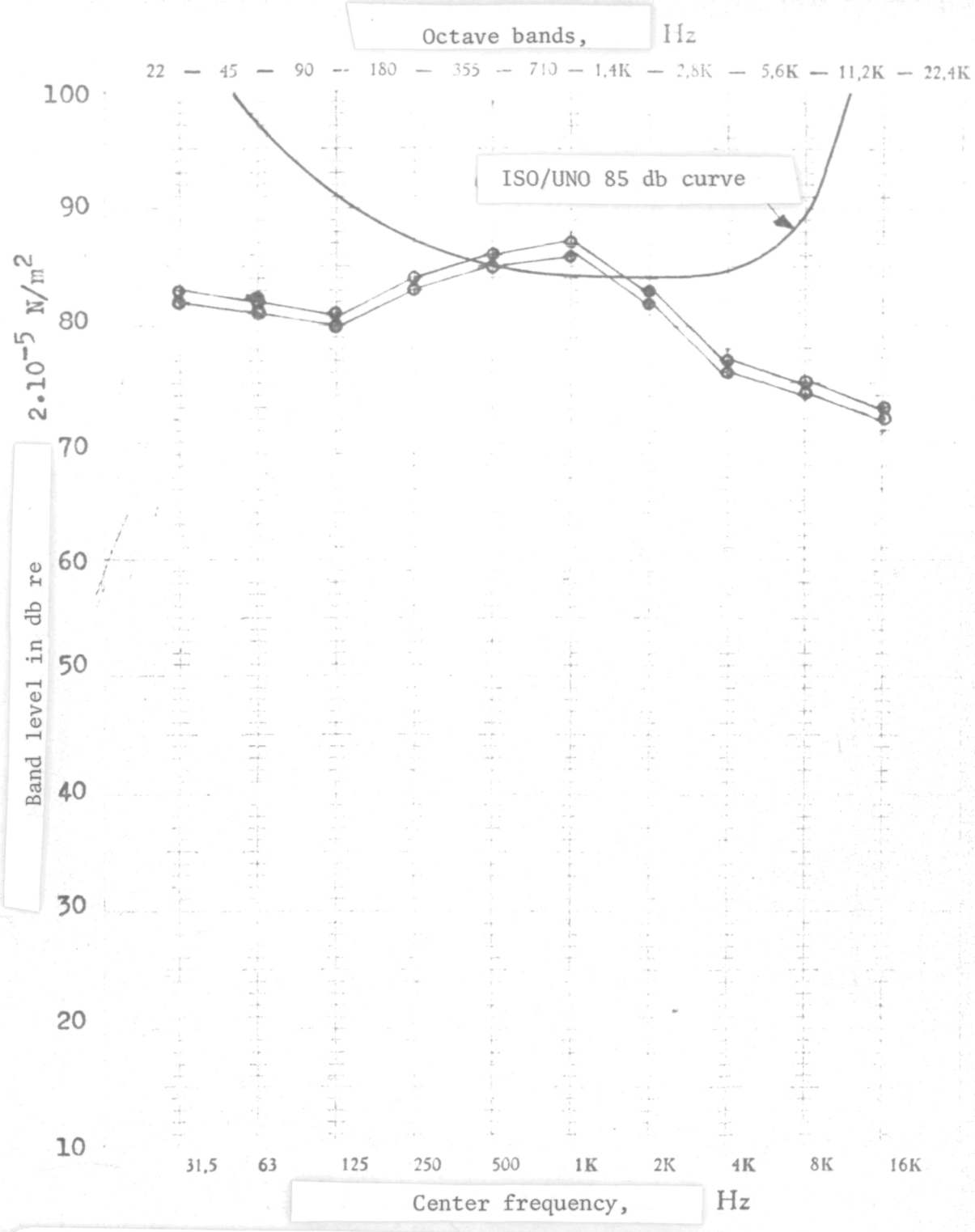
CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 15 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum overall levels, db	98	99	103	102
Minimum overall levels, db	97	98	102	101

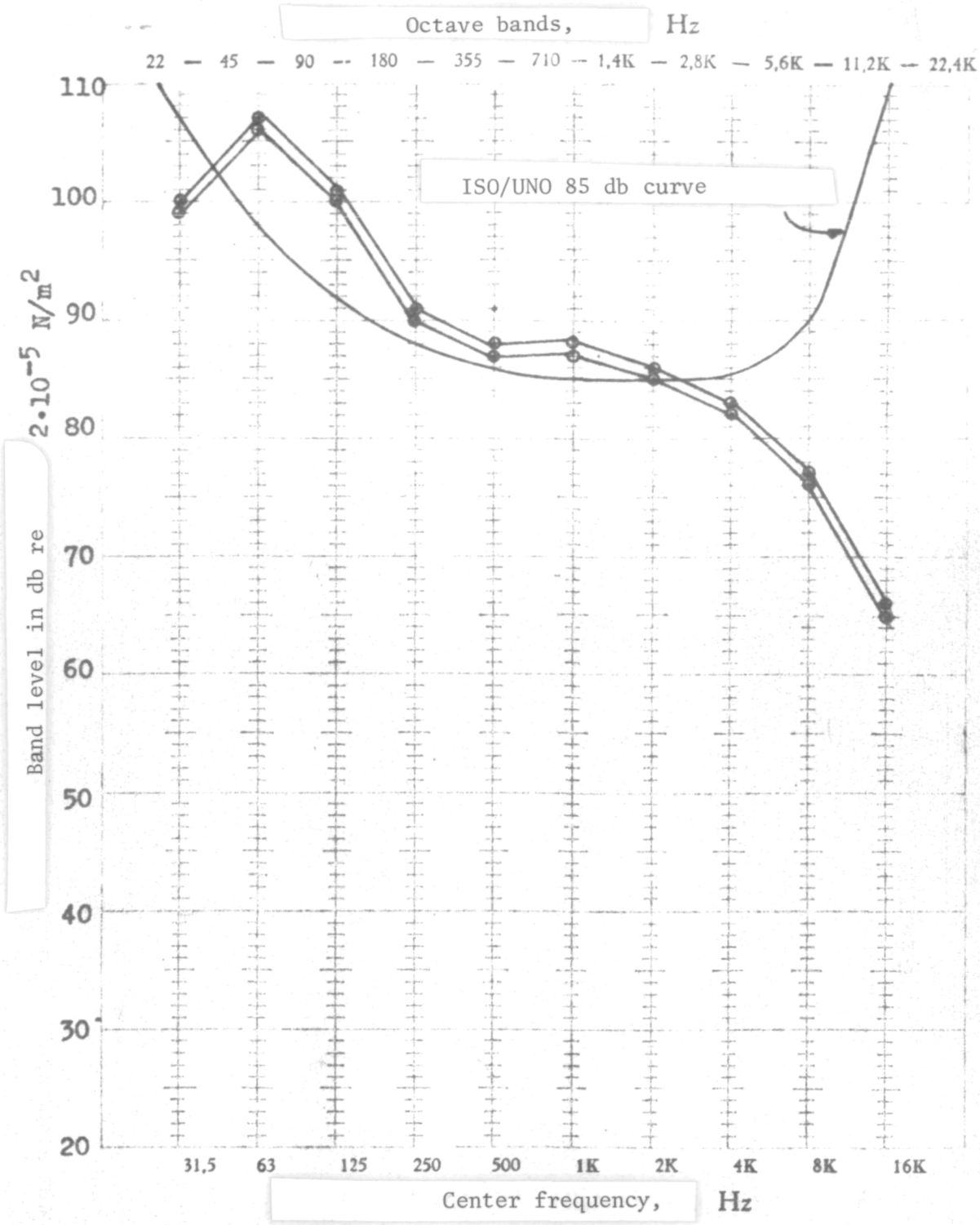
ACÚSTICA SÔNICA	LABORATÓRIO DE ACÚSTICA E SÔNICA S/C/L — C. P. 12.946 R. Esmeralda, 149 - S. Paulo	DATA 691010 NÚMERO 386-15/31	CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 16 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum overall levels, db	92	91	94	94
Minimum overall levels, db	91	90	93	93

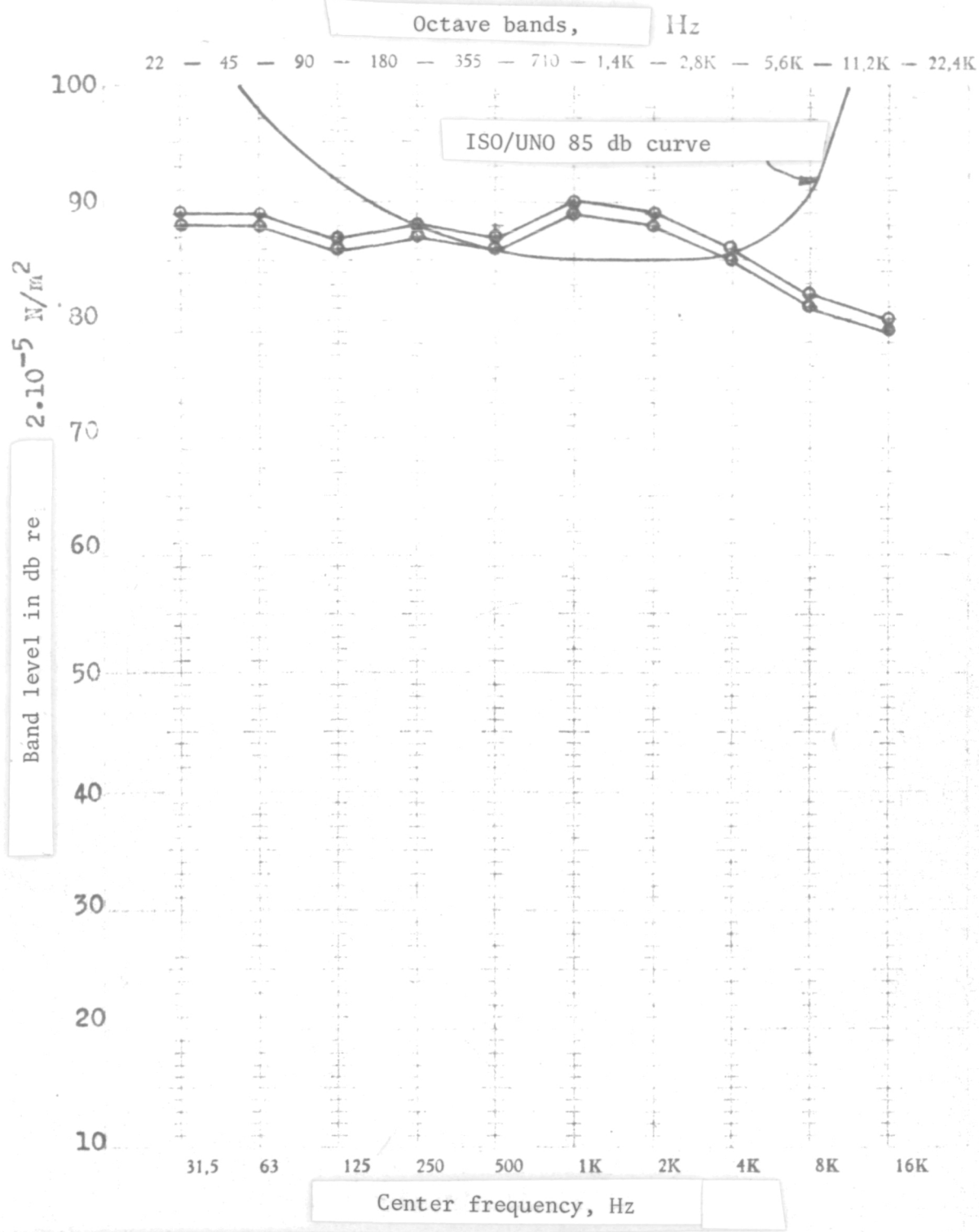
ACÚSTICA SÔNICA	LABORATÓRIO DE ACÚSTICA E SÔNICA S/C/L — C. P. 12.946 R. Esmeralda, 149 - S. Paulo	DATA 691010 NÚMERO 386-16/31	CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 17 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum overall levels, db	94	102	107	108,5
Minimum overall levels, db	93	101	106	108

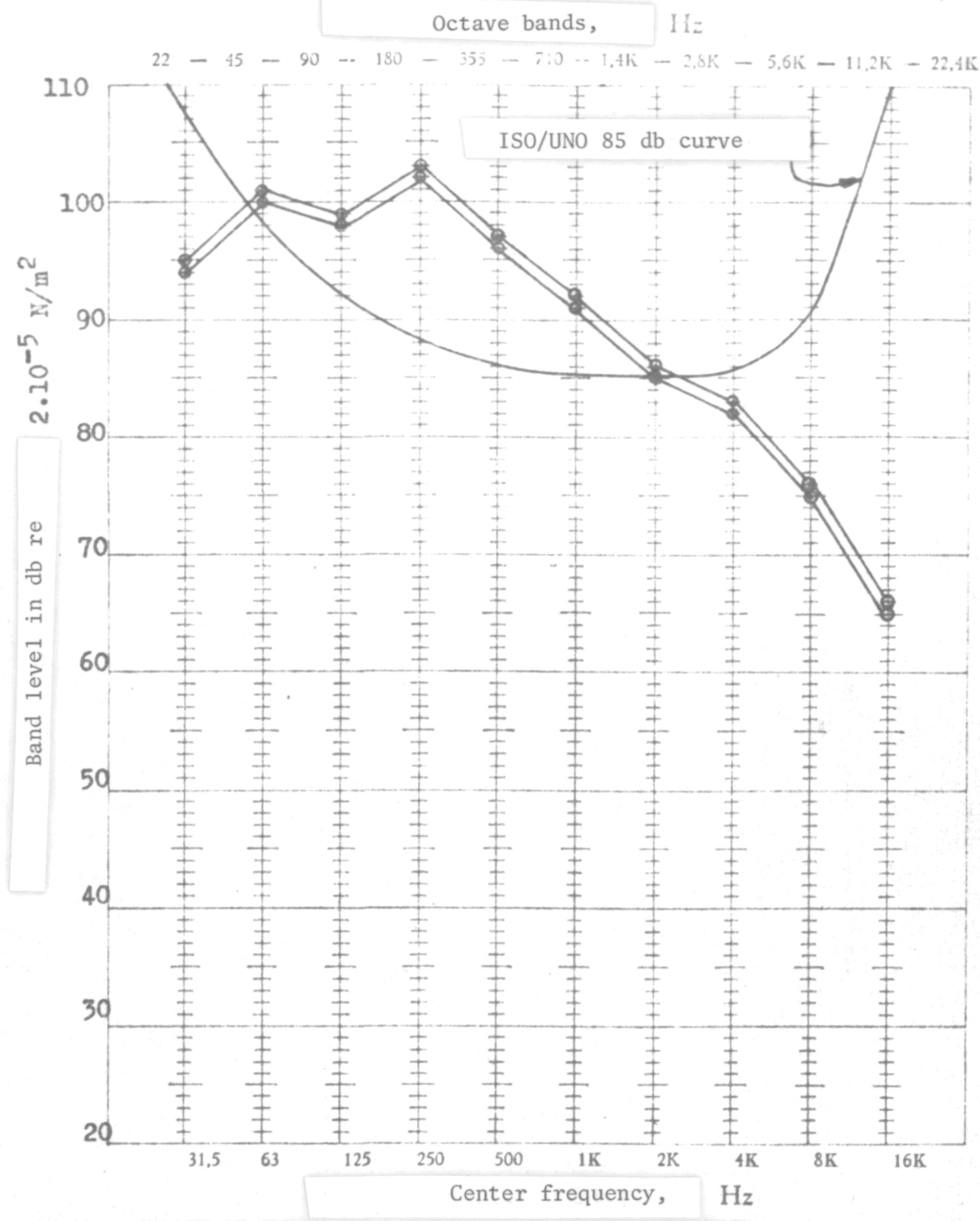
ACÚSTICA SÔNICA	LABORATÓRIO DE ACÚSTICA E SÔNICA S/C/L — C. P. 12.946 R. Esmeralda, 149 - S. Paulo	DATA 691010 NÚMERO 386-17/31	CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 18 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum overall level, db	97	98	99	99
Minimum overall level, db	96	97	98	98

ACÚSTICA SÔNICA	LABORATÓRIO DE ACÚSTICA E SÔNICA S/C/L — C. P. 12.946 R. Esmeralda, 149 - S. Paulo	DATA 691010 NÚMERO 386-18/31	CONEXÕES DE FERRO FOZ S/A



Measurements taken at location No. 19 indicated on Figure 386-1/31

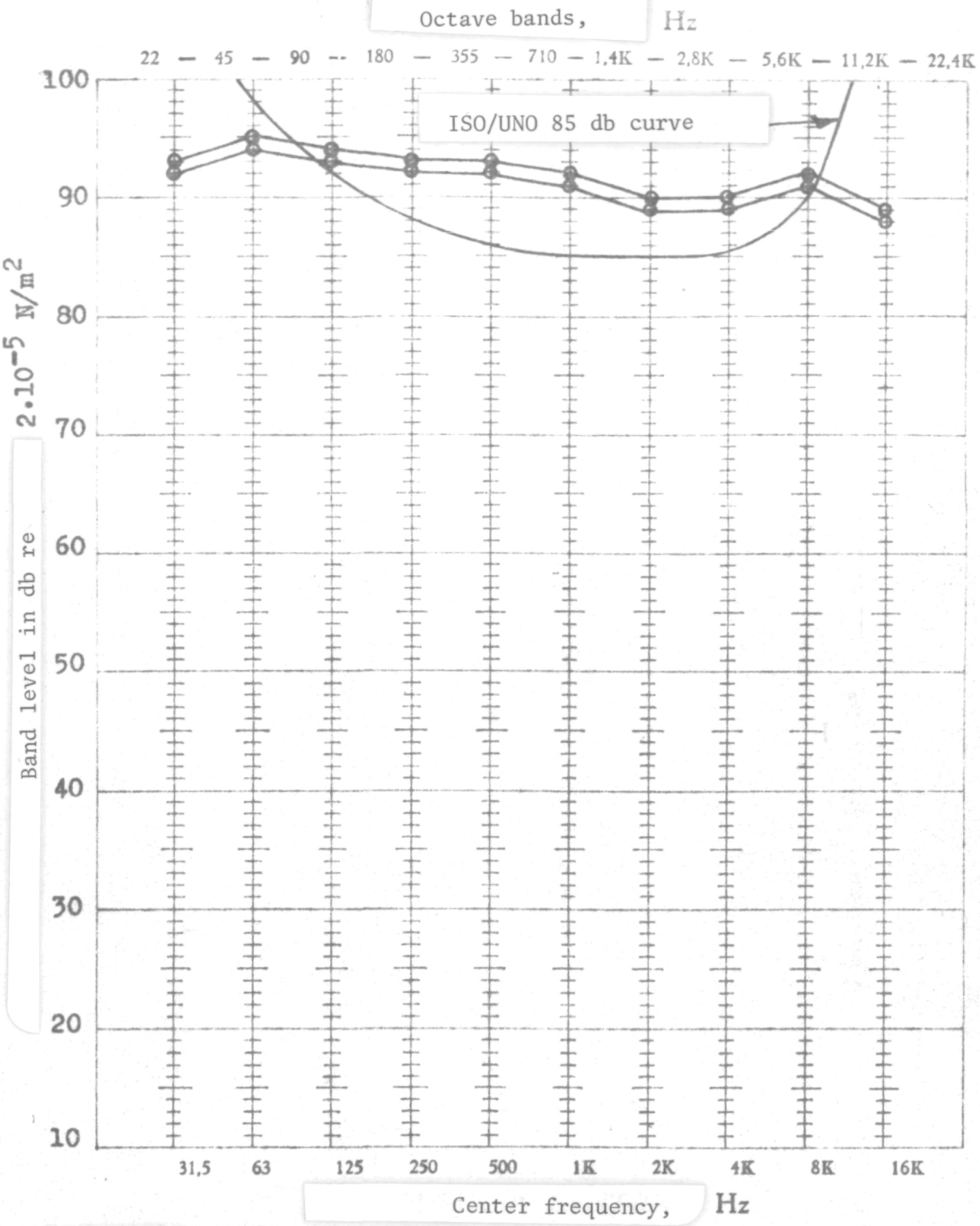
Compensation scale	A	B	C	L
Maximum overall level, db	100	105	106,5	107
Minimum overall level, db	99	104	105,5	106

ACÚSTICA SÔNICA
LABORATÓRIO DE ACÚSTICA E SÔNICA
S/C/L — C. P. 12.946
R. Esmeralda, 149 - S. Paulo

DATA 691010

NÚMERO 386-19/31

CONEXÕES DE FERRO FOZ S/A



c Measurements taken at location No. 20 indicated on Figure 386-1/31

Compensation scale	A	B	C	L
Maximum overall level, db	102	103	104	104
Minimum overall level, db	101	102	102	103

ACÚSTICA SÔNICA
LABORATÓRIO DE ACÚSTICA E SÔNICA
S/C/L — C. P. 12.946
R. Esmeralda, 149 - S. Paulo

DATA 691010

NÚMERO 386-20/31

CONEXÕES DE FERRO FOZ S/A

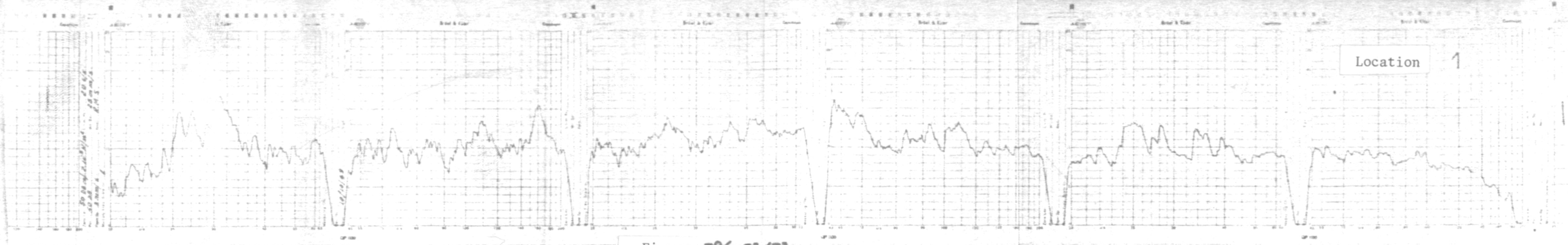


Figure 386-21/31

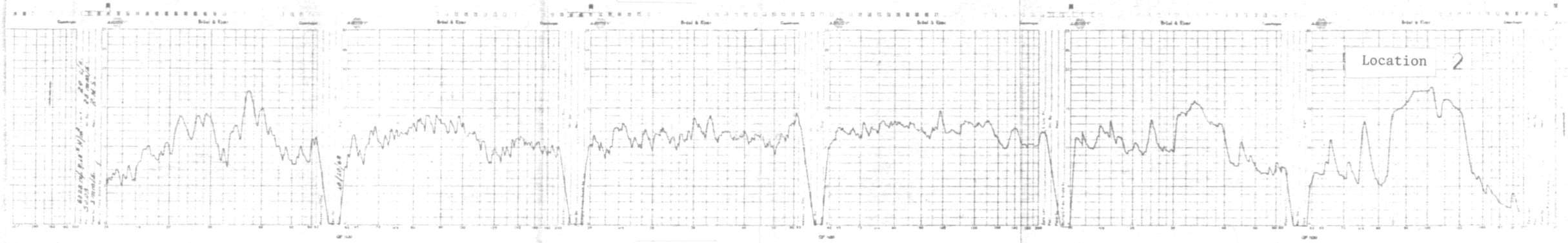


Figure 386-22/31

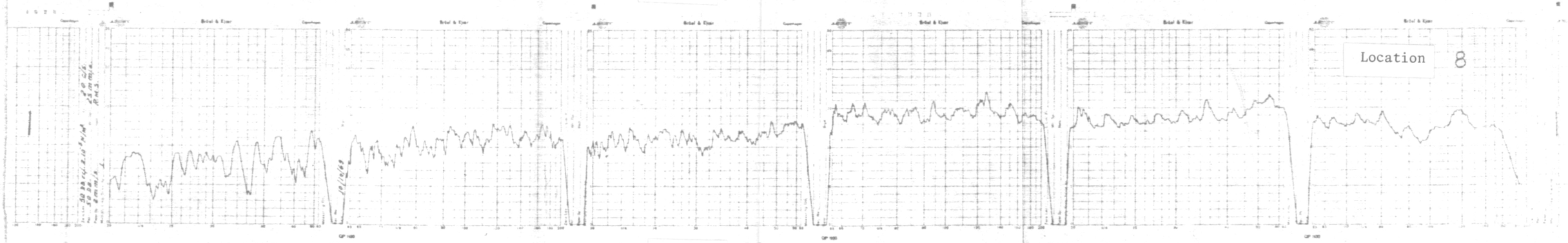


Figure 386-23/31

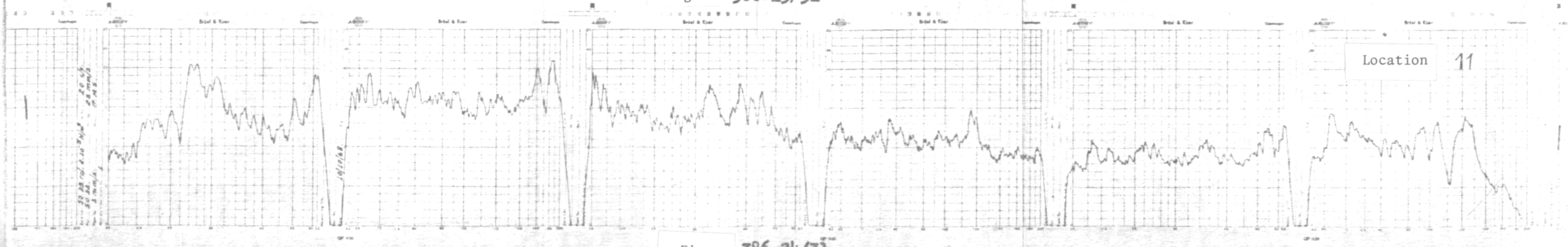


Figure 386-24/31

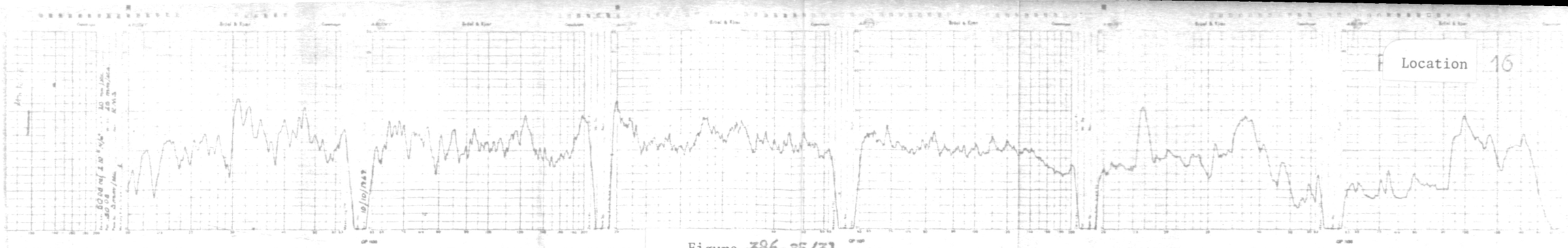


Figure 386-25/31

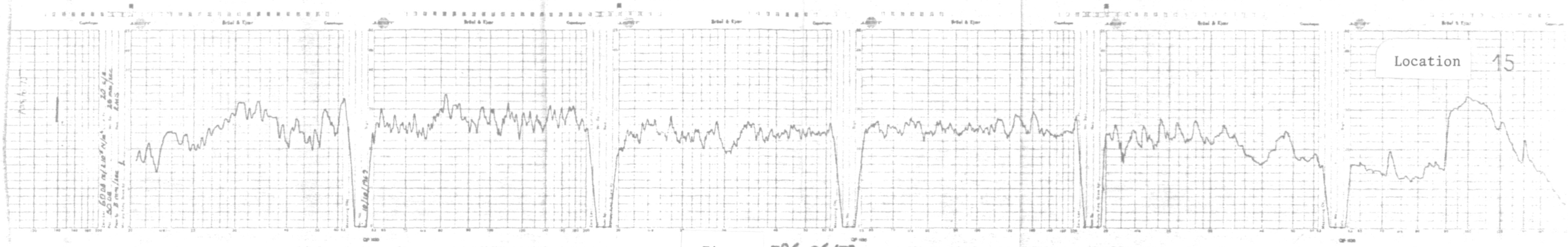


Figure 386-26/31

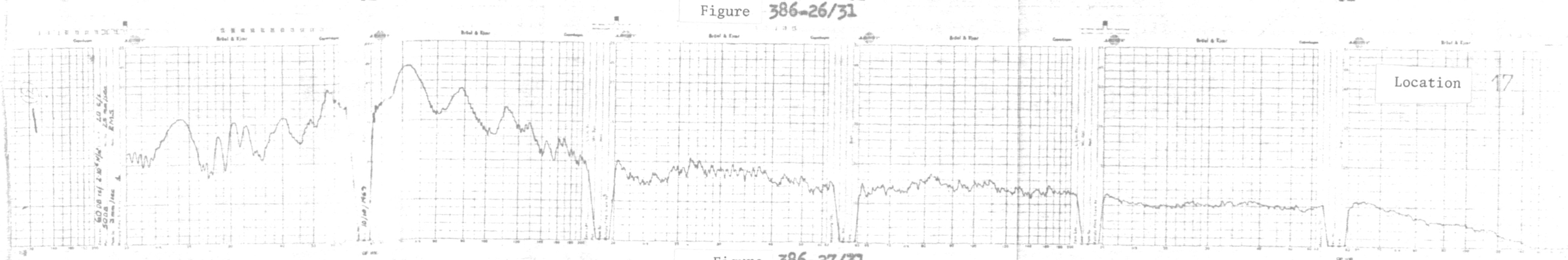


Figure 386-27/31

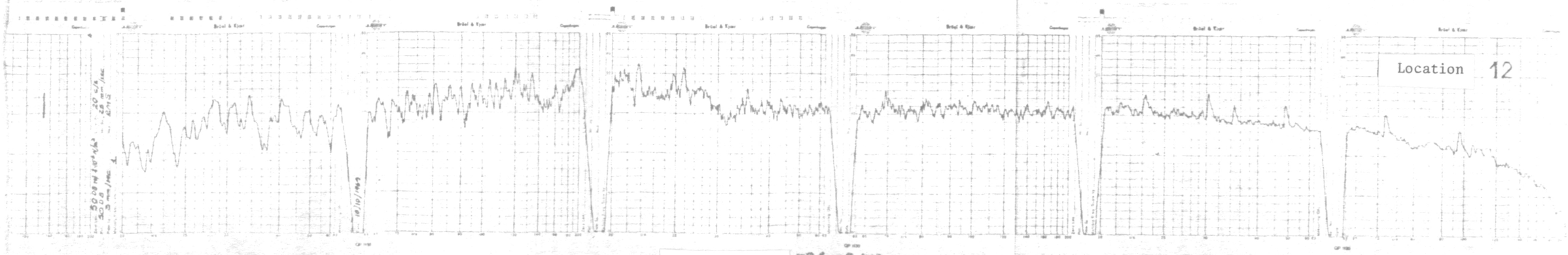


Figure 386-28/31

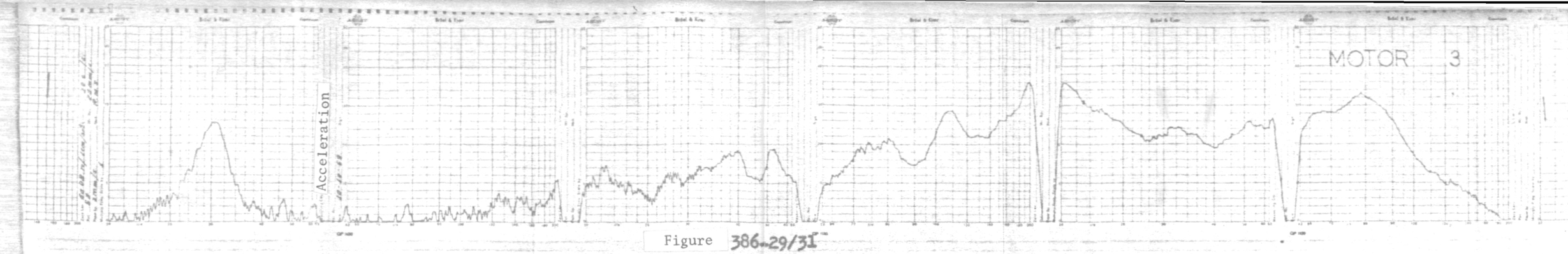


Figure 386-29/31

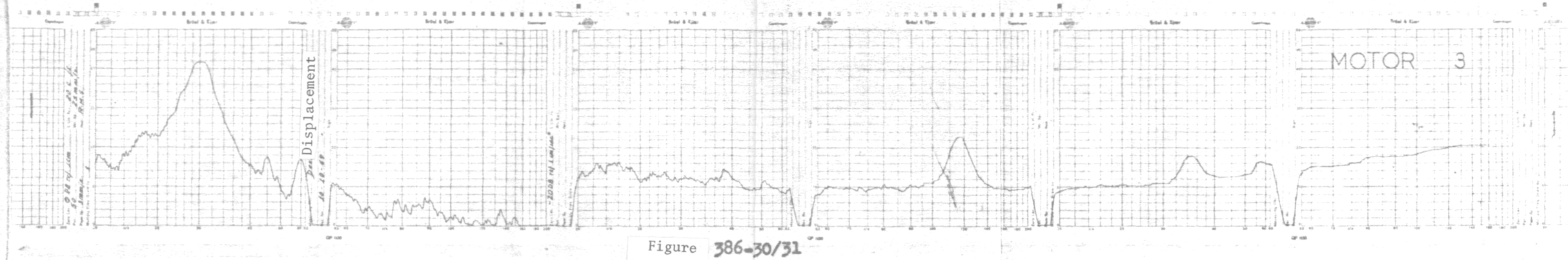
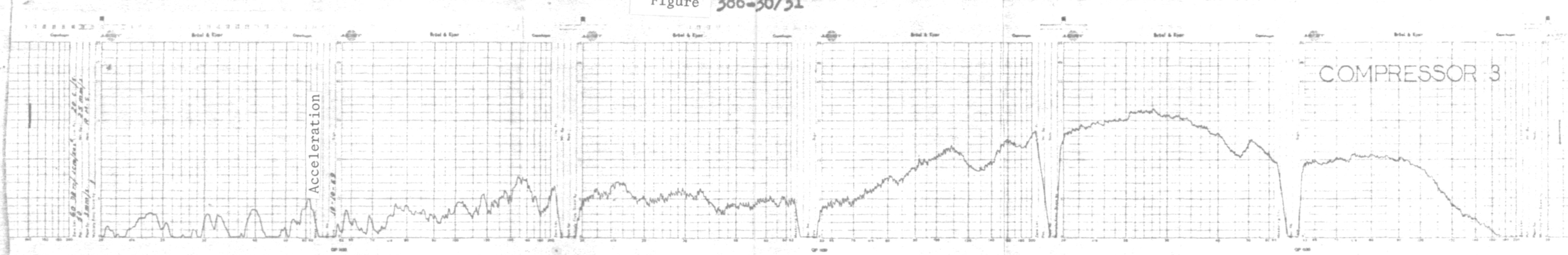


Figure 386-30/31



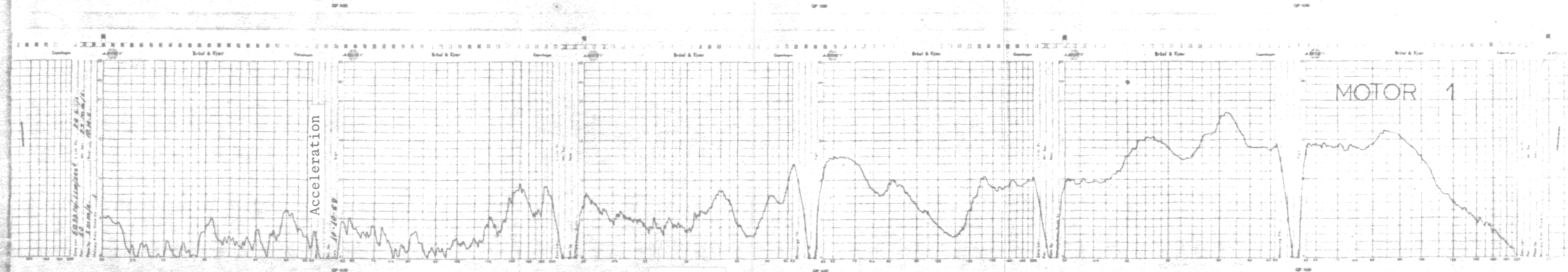


Figure 386-31/31